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ANALYSIS OF MULTIMODE FIBER COUPLERS, TAPERS AND MODE CONVERTER--ETC(U)

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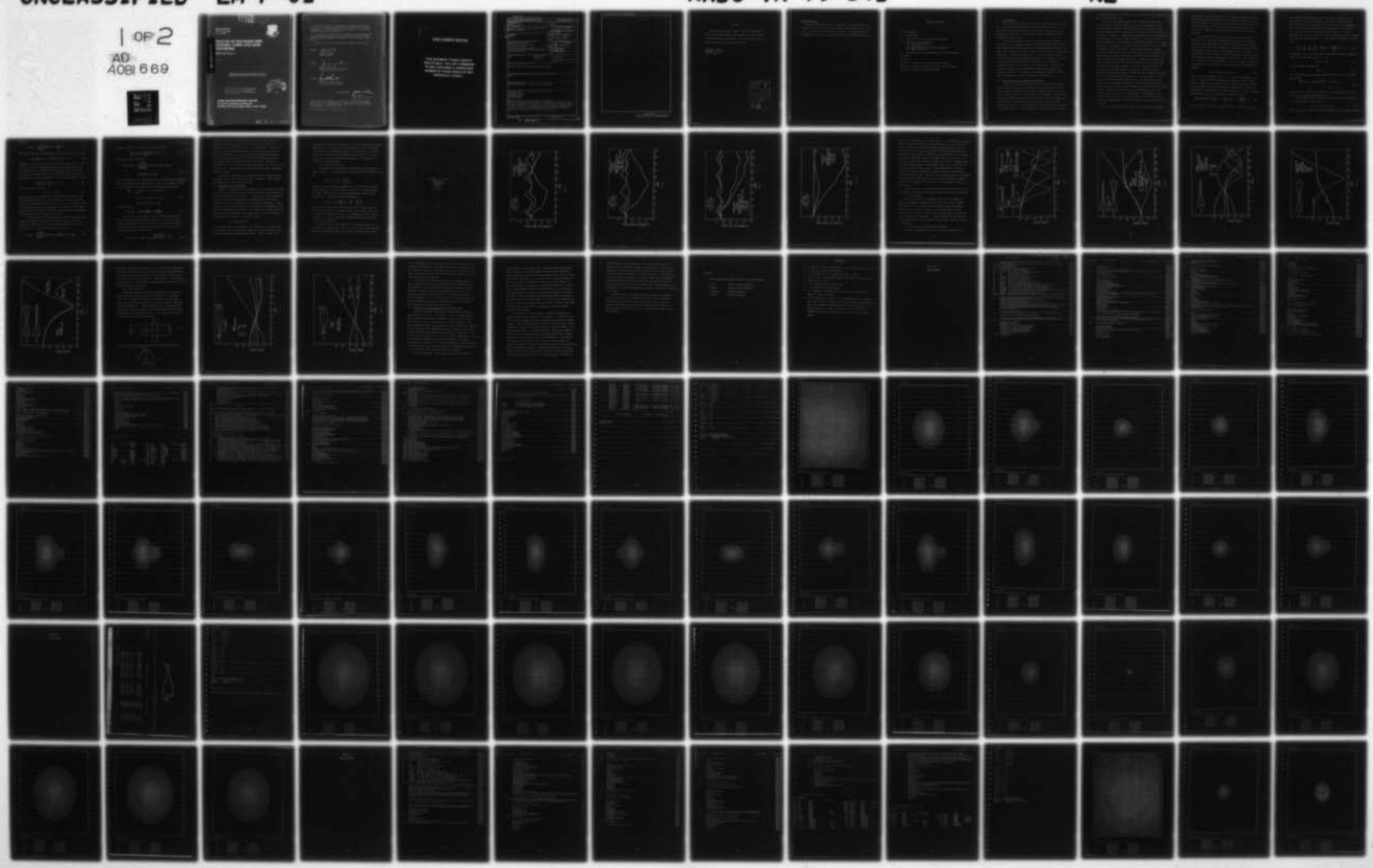

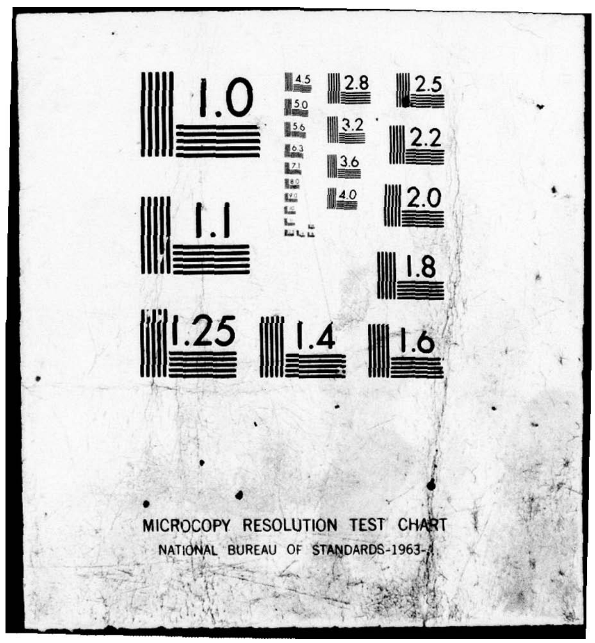
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(12)

RADC-TR-79-341
Final Technical Report
January 1980

ANALYSIS OF MULTIMODE FIBER COUPLERS, TAPERS AND MODE CONVERTERS

EMTEC Engineering Inc.

C. Yeh

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a final report on the analysis of multimode fiber couplers, tapers and mode converters. A method based on the fast Fourier transform technique of scalar wave equation has been successfully developed to yield numerical results on a number of practical multimode fiber components. Included in this report are listings of the computer programs.

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EVALUATION

This contract has provided computer simulation of the behavior of of various components of fiber optic transmission systems, relevant to TPO 3B, Optical Communications. The results obtained will be useful in optimizing the design of such systems.

Leonard J. Eyges
LEONARD J. EYGES
Project Engineer

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Personnel

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I. Introduction

This final report summarizes the work performed under Contract No. F19628-78-C-0206 which the Electronic Systems Division of the Air Force Systems Command granted to the EMtec Engineering, Inc. Los Angeles, California. The work was begun in August, 1978 and completed in August, 1979.

The major objectives of this R & D study were to perform theoretical and numerical analysis of multimode fiber optic components. Specifically, the following multimode components were studied: (a) Dual Fiber Couplers, (b) Fiber Tapers, (c) Fiber Horns and Branching Waveguides, and (d) Mode Converters. In the following we shall first present some background information on this subject and then our mathematical approach will be delineated. In Section III selected results of our study are then summarized. Finally, the concluding remarks and recommendations for future work will be given in Section IV. Listings of the important computer programs that we developed are also included in the Appendix.

II. Background and The Mathematical Approach

There are currently strong trends in system design toward microminiaturization digital processing and system level integration in order to achieve smaller size, weight, and power consumption, along with lower cost and improved reliability. These trends naturally point to data bus multiplexing, i.e., the interconnection of a number of spatially distributed terminals via fiber optic waveguides cables. The key component for any fiber data bus system is the fiber coupler. Since multimode singlestrand fiber is used as

a communication link in a data bus system, multimode fiber couplers must be designed and used.

To design any coupler properly for a multimode single fiber data bus system, detailed analysis of waveguide propagation must be carried out. Existing techniques based on the finite elements method,[1] the coupled mode theory,[2] or the geometrical optics method[3] are usually inadequate. (Detailed discussions have been included in a review paper which would appear shortly[4].) Although the finite elements method is a very powerful approach when dealing with single-mode fibers or couplers, it is very inefficient and costly (in terms of computer time) to obtain any results for multimode structures. Similarly, coupled mode theory has been used quite successfully in predicting the coupling efficiencies of single-mode structures, but cannot be used for multimode structures. Although the geometrical optics method using the ray-tracing technique may yield zero-order results for multimode structures, it is too crude to predict the wave behavior of light signals in couplers. Recently, Arnard[5] developed a technique based on the Cook adiabatic coupler principle[6] to treat the multimode coupler problem. He claims that "it may be used to couple two optical fibers because the dimensions are not critical; only slowness is required". Our technique, given below, will provide more accurate results because it does not involve making a priori assumptions on the relevance of the dimensions of the structure and the slowness of the coupling. Furthermore, this technique may be used to study mode conversion effects due to the nonuniform distribution of dielectric material withint the guided structure.

It is noted that analysis based on the scalar wave approxima-

tion has been very successful in predicting the properties of many optical devices whose characteristic dimensions are on the order of many wavelengths. The scalar wave approach is therefore preferred. We have developed an efficient numerical technique based on the scalar wave equations to solve problems dealing with multimode couplers.

It is well known that solving the exact electromagnetic equations for a spatially inhomogeneous medium is a formidable problem. Multimode couplers and mode converters can be approximated by structures with a spatially nonuniform dielectric medium. Fortunately, there are some approximations that can be made to simplify this task. First, the light wavelengths of interest are much shorter than the inhomogeneity scale length. This enables us to neglect polarization effects. Hence, the optical field can be derived from a scalar u(x,z) that satisfied the reduced wave equation[7]

$$[\nabla^2 + k^2 n^2(\underline{x},z)]\, u(\underline{x},z) = 0 \quad , \qquad (1)$$

where k is the wavenumber $2\pi/\lambda$, λ is the laser wavelength, and $n(\underline{x},z)$ is the spatially inhomogeneous refractive index of the medium. Second, if we write u as the product of a factor $e^{ikn_o z}$ that accounts for the rapid change in the phase of u along the direction cf propagation and a complex amplitude $A(\underline{x},z)$, a further simplification of the calculational problem results:

$$\left[i2kn_o \frac{\partial}{\partial z} + \nabla_T^2 + k^2\left(n^2(\underline{x},z) - n_0^2\right)\right] A(\underline{x},z) = -\frac{\partial^2 A(\underline{x},z)}{\partial z^2} \quad , \qquad (2)$$

where ∇_T^2 is the transverse Laplacian $\partial^2/\partial x^2 + \partial^2/\partial y^2$ and n_o is a

given constant which represents the refractive index of some uniform medium. At laser wavelengths, the complex amplitude $A(\underline{x})$ varies much more rapidly transverse to the direction of propagation than it does along the direction of propagation. This enables us to make the paraxial approximation and neglect the term on the right side of Eq. (2) (in the Russian literature this is called the parabolic approximation). So, the complex amplitude now satisfies

$$\left[i2kn_o \frac{\partial}{\partial z} + \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + k^2\left(n^2(\underline{x}, z) - n_0^2\right)\right] A(\underline{x}, z) = 0 \quad . \qquad (3)$$

In addition to Eq. (3), the complex amplitude satisfies an initial condition on the fiber end; at $z = 0$,

$$A(\underline{x},0) = u(\underline{x},0) \qquad (4)$$

and the boundary condition is

$$A(\underline{+}\infty, z) = 0 \quad . \qquad (5)$$

If a truncated guassian beam is focused on one end of the optical guide, then

$$\begin{aligned} u(x,y,o) &= u_o \exp(-r^2/w^2) \qquad \text{for } 0 \leq r \leq b \\ &= 0 \qquad \text{for} \quad r > b \quad , \end{aligned} \qquad (6)$$

where $r^2 = x^2 + y^2$, w is the spot size of the beam, and b is the radius of the truncated beam at $z = 0$.

We have solved Eq. (3) numerically in the following manner. Let us write $A(\underline{x},z)$ in the form

$$A(\underline{x},z) = \exp[\Gamma(x,z)]\, v(\underline{x},z) \quad , \qquad (7)$$

where $\Gamma(\underline{x},z)$ is a phase function associated with the medium inhomo-

geneities

$$\Gamma(\underline{x}, z) = \frac{ik}{2n_o} \int_{z_o}^{z} \left[n^2(x, y, z') - n_0^2\right] dz' \quad . \tag{8}$$

The modified complex amplitude $v(\underline{x},z)$ then satisfies the equation

$$i2kn_o \frac{\partial}{\partial z} v(\underline{x}, z) + e^{-\Gamma} \nabla_T^2 \left[e^{\Gamma} v(\underline{x}, z)\right] = 0 \quad . \tag{9}$$

Although Eq. (9) does not look any easier to solve than Eq. (3), it is easier to solve numerically because, for sufficiently small increments in the z direction and an appropriately chosen lower limit in the integral in Eq. (8), the value of $v(x,y,z + \Delta z)$ can be obtained to a good approximation by solving the simpler equation

$$\left[i2kn_o \frac{\partial}{\partial z} + \nabla_T^2\right] v(\underline{x}, z) = 0 \tag{10}$$

with the initial condition

$$v(x,y,0) = u(x,y,0) \quad . \tag{11}$$

Physically, these equations approximate the propagation in the inhomogeneous medium by a two-step process at each z increment. First, we propagate the field $u(\underline{x},z)$ at z to $z + \Delta z$ assuming that the intervening space is homogeneous. The effect of the inhomogeneities between z and $z + \Delta z$ is then accounted for by multiplying this solution by the phase factor $\exp\Gamma$.

In this research we have solved Eq. (10) by the fast Fourier transform technique. Replacing the Laplacian by its finite difference equivalent but still retaining the z derviative, the solution of Eq. (10) can be expressed in the form

$$v(m, n, z) = \sum_{m', n'=0}^{N-1}\sum V(m', n', z) \exp\left[\frac{i2\pi}{N}(mm' + nn')\right] \quad , \tag{12}$$

where $x = m\Delta x$, $y = n\Delta x$, and $V(m', n', z)$ satisfy

$$\left[i2kn_o \frac{\partial}{\partial z} + \frac{f(m', n')}{(\Delta x)^2}\right] V(m', n', z) = 0 \tag{13}$$

with the initial conditions

$$V(m', n', z_i) = \frac{1}{N^2} \sum\sum_{m,n=0}^{N-1} v(m, n, z_i) \exp[\Gamma(m, n, z_i)]$$
$$\exp\left[-\frac{i2\pi}{N}(m'm + n'n)\right]. \tag{14}$$

The function $f(m', n')$ is determined by the difference approximation used to represent the Laplacian in Eq. (10). For example, if $\nabla_T^2 v$ is approximated by the simple central difference expression

$$\nabla_T^2 v = \frac{1}{(\Delta x)^2} [v(m + 1, n, z) - 2v(m, n, z)$$
$$+ v(m - 1, n, z) + v(m, n + 1, z) \tag{15}$$
$$- 2v(m, n, z) + v(m, n - 1, z)]$$

then $f(m', n')$ is

$$f(m', n') = -4\left[\sin^2\left(\frac{\pi m'}{N}\right) + \sin^2\left(\frac{\pi n'}{N}\right)\right]. \tag{16}$$

Note that the series in Eq. (12) is simply the discrete Fourier transform of the function $V(m', n', z)$, and thus can be evaluated numerically for a given $V(m', n', z)$ by a fast Fourier transform algorithm. Furthermore, the function $V(m', n', z)$ is readily determined from Eq. (13) as

$$V(m', n', z) = V(m', n'z_i) \exp\left[\frac{-if(m', n')}{2k(\Delta x)^2 n_o}(z - z_i)\right], \tag{17}$$

where $V(m',n',z_i)$ is given by the series in Eq. (14), which can also be evaluated by a fast Fourier transform algorithm. To summarize, we will step from z to $z + \Delta z$ as follows: (1) take the inverse discrete Fourier transform of $u(m,n,z) = [\exp \Gamma(m,n,z)] \cdot v(m,n,z)$ by means of an inverse fast Fourier transform algorithm; (2) multiply the result by $\exp [-if(m',n')\Delta z/2k(\Delta x)^2 n_o]$ and take the discrete Fourier transform with a fast Fourier transform algorithm; and (3) multiply the result by $\exp[\Gamma(m,n,z + \Delta z)]$ to yield $u(m,n,z + \Delta z)$. This process is repeated until we have reached the desired z plane.

Using this algorithm we have been successful in obtaining many meaningful results for various multimode structures. These results are summarized in the following section.

III Multimode Fiber Components

Before we proceed with the presentation of the numerical results, it should be recalled that we are dealing completely with total field quantities and not with the modes. In other words, we are interested in how the total field evolves as it propagates down the guiding structure; we are not interested in how each mode propagates. Nevertheless, it is recognized that the total field may be decomposed into a set of orthonormal guided modes. For example, an incident Gaussian beam with a given beamwidth w may excite many modes in a parabolic-index-profile fiber when $\alpha > 1$ or when $\alpha < 1$ with

$$\alpha = (2\lambda a)/[\pi n_a w^2 (2\delta)^{1/2}]$$

or may excite only one mode when $\alpha = 1$. Only the $\alpha = 1$ single mode will propagate down the parabolic-index-profile guide without experiencing the focusing and defocusing effects. For $\alpha \neq 1$ cases, the

input Gaussian beam will experience focusing and defocusing effects. Another way to interpret the above phenomenon is that multimodes with different propagation constants are excited by the input beam when $\alpha \neq 1$, while only single mode is excited when $\alpha = 1$. The stronger are the focusing-defocusing effects, the higher is the content of different modes.

(a) Dual Fiber Couplers

The geometry of a multimode inhomogeneous fiber coupler is shown in Fig. 1. Two graded-index fibers with index variation given by

$$n\left(r_{1.2}\right) = n_a \left(1 - \delta \frac{r_{1,2}^2}{a_{1,2}}\right),$$

where $r_{1,2}$ are the radial coordinates of 1 and 2 fibers, respectively, and n_a, δ, a are all known constants, are fused together as shown. The separation distance between the centers of the fibers is d. A Gaussian beam representable by

$$u(x,y) = u_o \exp\left\{\left[-\left(x + \frac{d}{2}\right)^2 - y^2\right]\Big/w^2\right\},$$

where u(x,y) is the scalar wave function of the beam, and u_o, w are given constants, is incident on one of the fibers. We wish to learn how this beam evolves as it propagates down the coupled structure. In other words, the coupling distance and the beam shape will be obtained.

Results of our investigation on the multimode dual fiber couplers are shown in Figs. 2-5. It is seen that if two identical parabolic-index fibers were placed side by side with each other

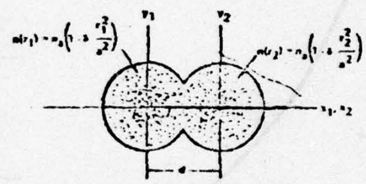
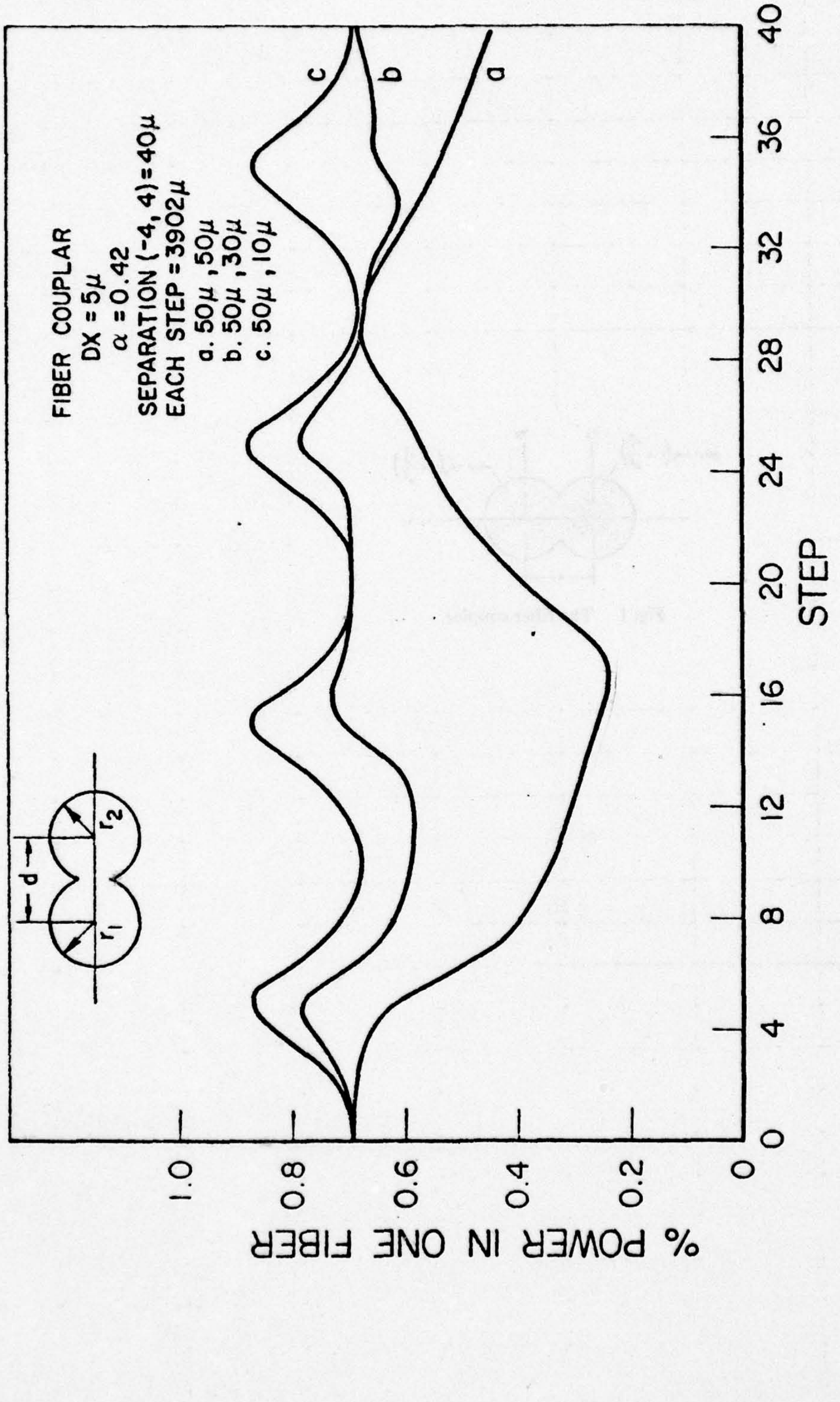


Fig. 1. The fiber coupler.



FIBER COUPLAR
DX = 5μ
α = 0.42
SEPARATION (-4, 4) = 40μ
EACH STEP = 3902μ
a. 50μ , 50μ
b. 50μ , 30μ
c. 50μ , 10μ
d
r1
r2
a
b
c
% POWER IN ONE FIBER
0
0.2
0.4
0.6
0.8
1.0
STEP
0
4
8
12
16
20
24
28
32
36
40

Figure 2

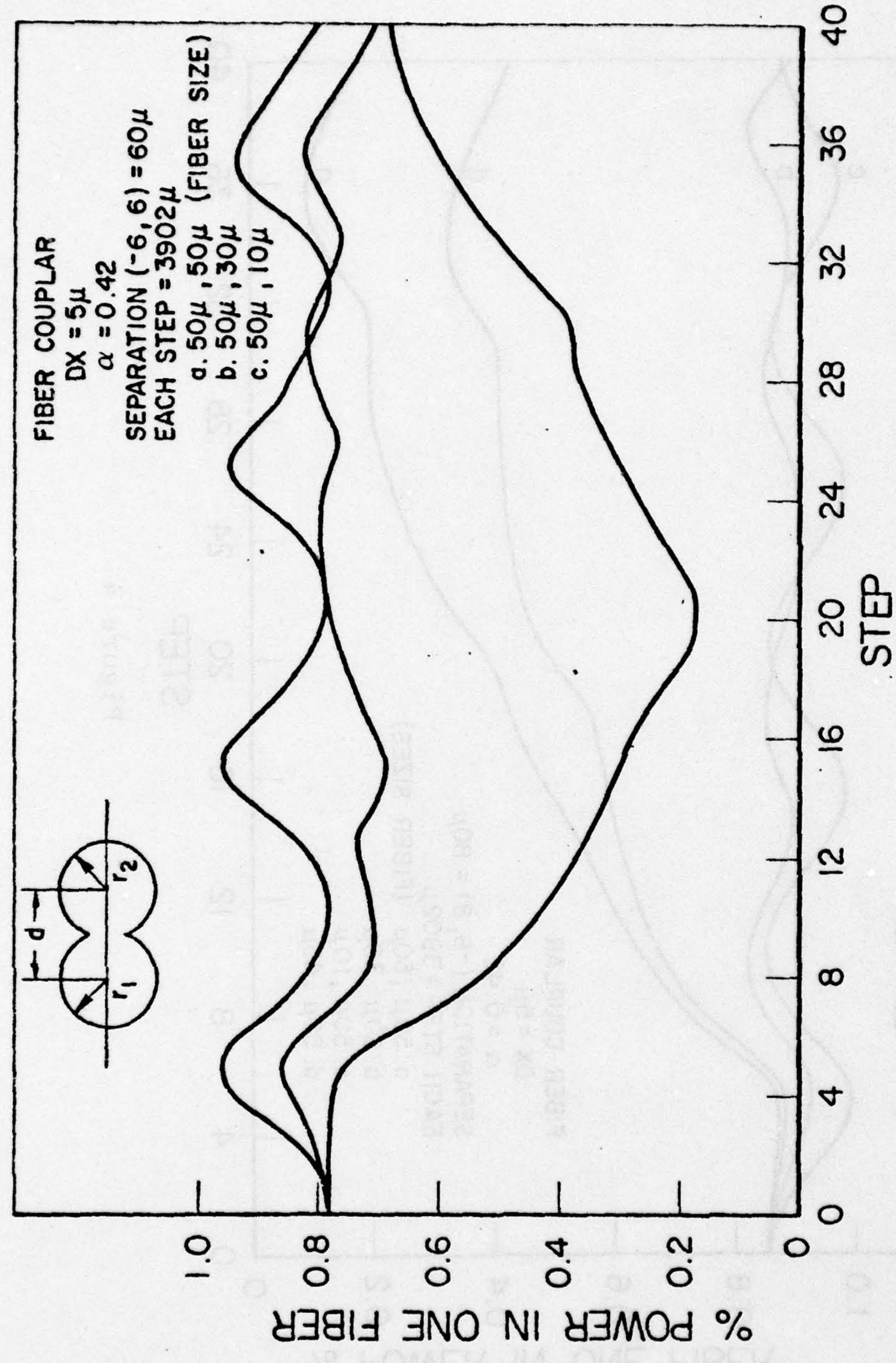

FIBER COUPLAR
DX = 5μ
α = 0.42
SEPARATION (-6, 6) = 60μ
EACH STEP = 3902μ
a. 50μ , 50μ (FIBER SIZE)
b. 50μ , 30μ
c. 50μ , 10μ
d
r1
r2
% POWER IN ONE FIBER
0
0.2
0.4
0.6
0.8
1.0
STEP
0
4
8
12
16
20
24
28
32
36
40

Figure 3

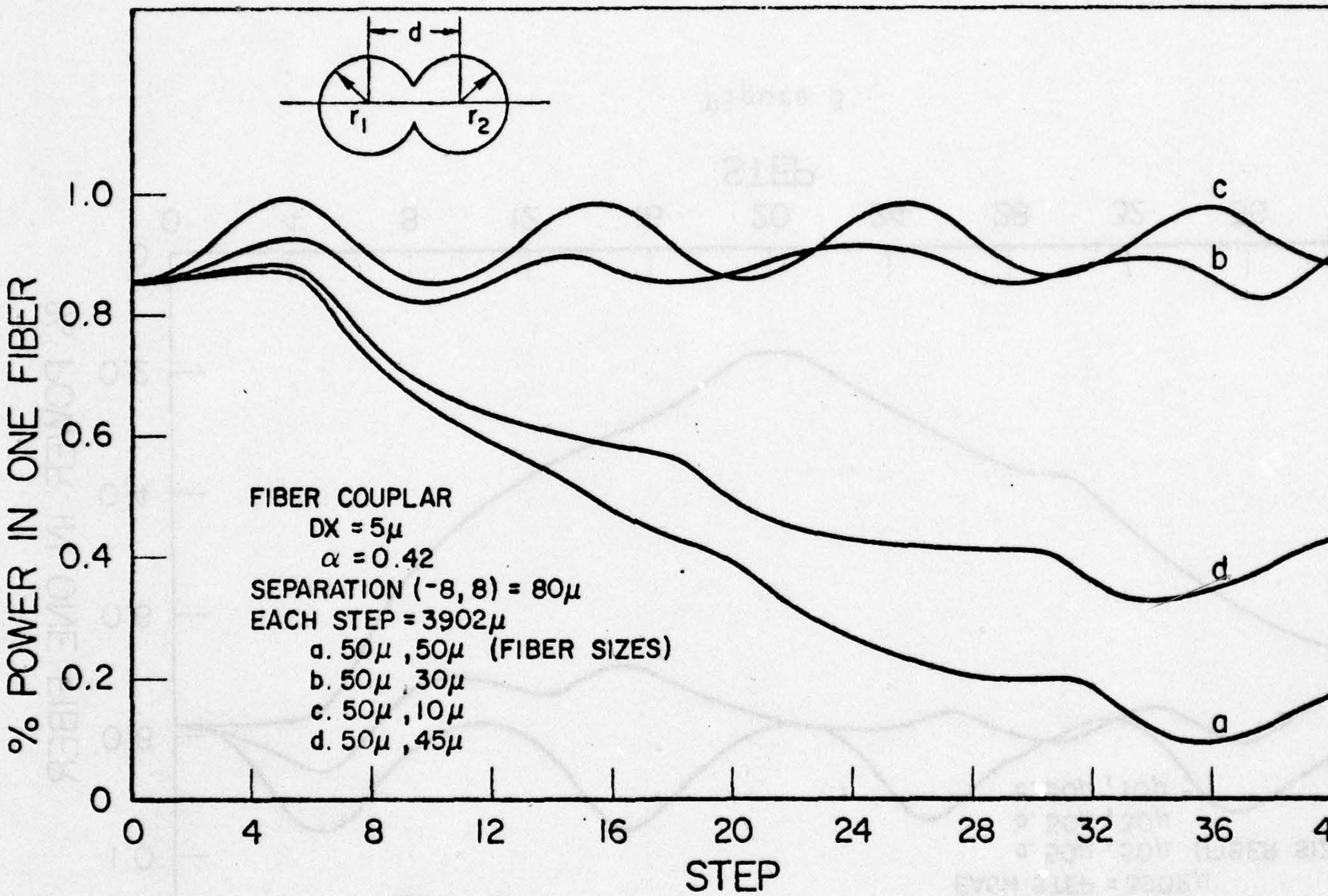

d
r_1
r_2
1.0
0.8
0.6
0.4
0.2
0
% POWER IN ONE FIBER
0
4
8
12
16
20
24
28
32
36
40
STEP
a
b
c
d
FIBER COUPLAR
DX = 5μ
α = 0.42
SEPARATION (-8, 8) = 80μ
EACH STEP = 3902μ
a. 50μ , 50μ (FIBER SIZES)
b. 50μ , 30μ
c. 50μ , 10μ
d. 50μ , 45μ

Figure 4

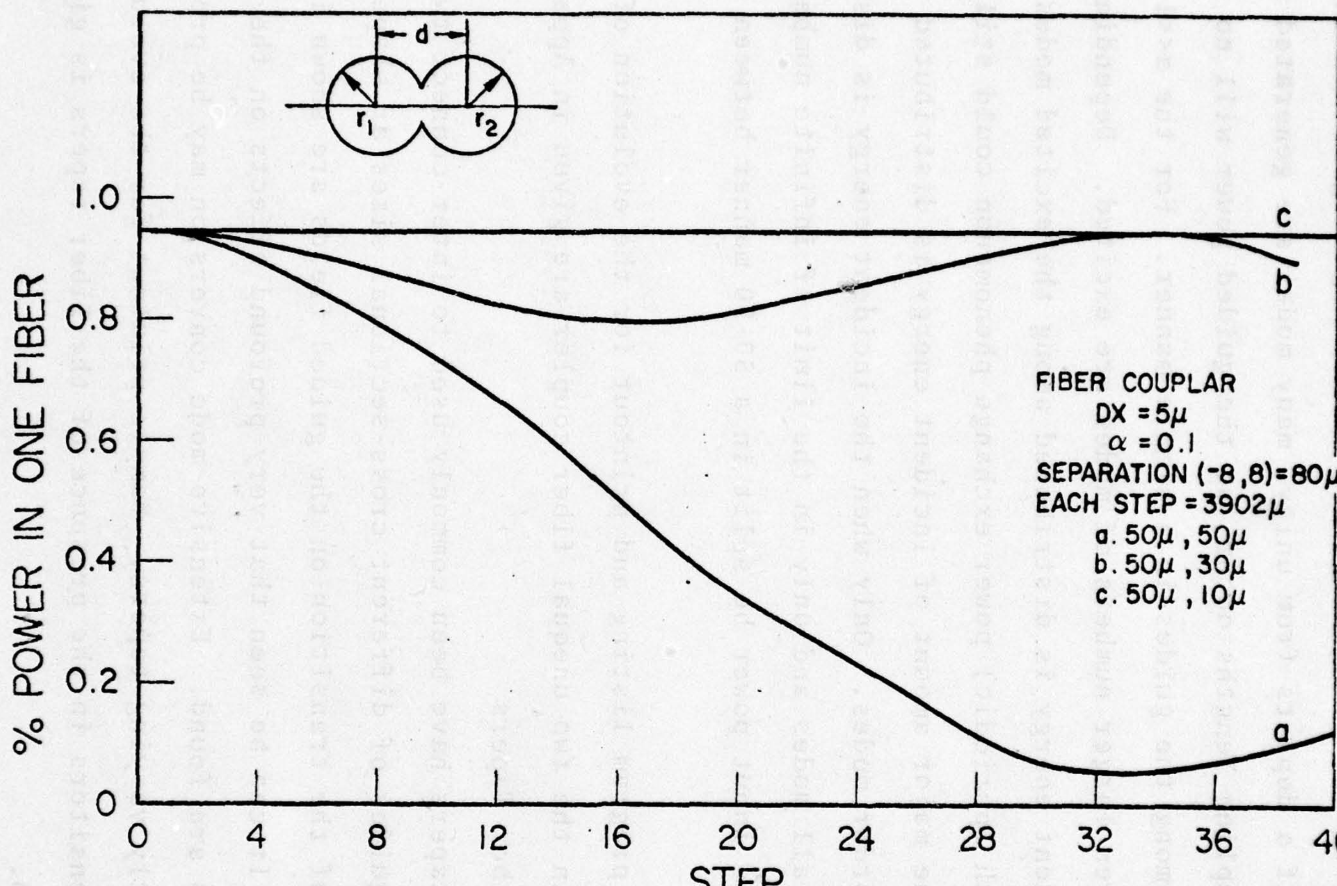

% POWER IN ONE FIBER
STEP
d
r_1
r_2
FIBER COUPLAR
DX = 5μ
α = 0.1
SEPARATION (-8,8) = 80μ
EACH STEP = 3902μ
a. 50μ, 50μ
b. 50μ, 30μ
c. 50μ, 10μ
a
b
c

Figure 5

and if the beamwidth were so chosen that $\alpha = 1$ is obtained, one would expect the guided power to interchange between the two fibers in a periodic manner with a distinct single coupling length. On the other hand, if α departs from unity, many modes are generated and many beat coupling lengths occur, so the guided power will no longer interchange among the guides in a simple manner. For the $\alpha<<1$ or $\alpha>>1$ case, even larger numbers of modes are excited. Depending upon how the incident energy is distributed among the excited modes the back and forth (periodic) power exchange phenomenon could still prevail if the major amount of incident energy is distributed in several low-order modes. Only when the incident energy is distributed evenly among all modes and only in the limit of infinite number of modes will the input power be split in a 50-50 manner between the two fibers.

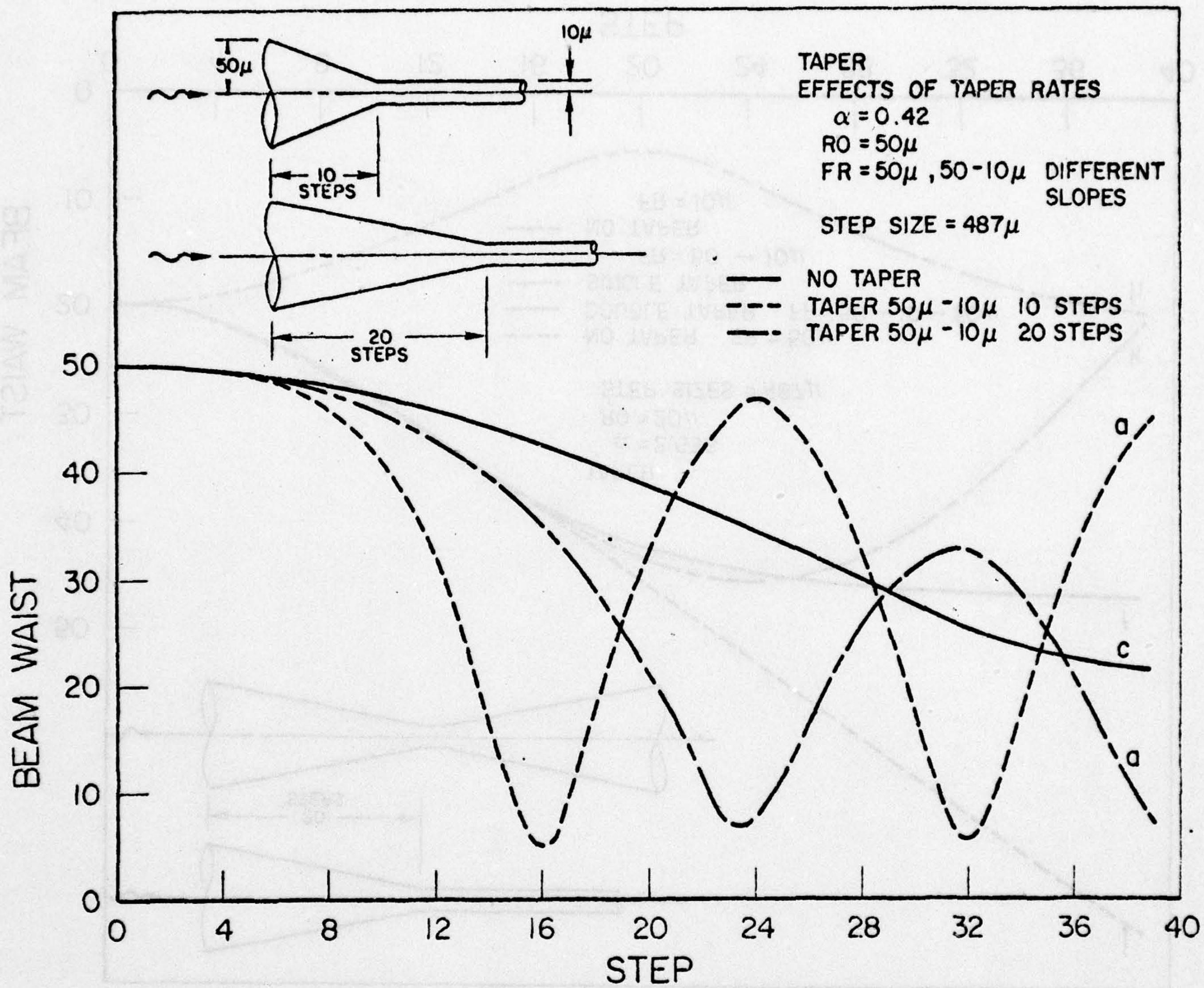
Sample program listing and printout for the evolution of field intensities in the two unequal fiber coupler are given in Appendix A.

(b) Fiber Tapers

Fiber tapers have been commonly used to inter-connect two optical waveguides of different cross-sectional sizes or shapes. The effects of the transition on the guided fields are shown in Figs. 6-10. It can be seen that very profound effects on the guided fields are found. Extensive mode conversion may be present even for gently varying tapers. Sample printout for the evolution of field intensiters in the presence of the fiber tapers is given in Appendix B.

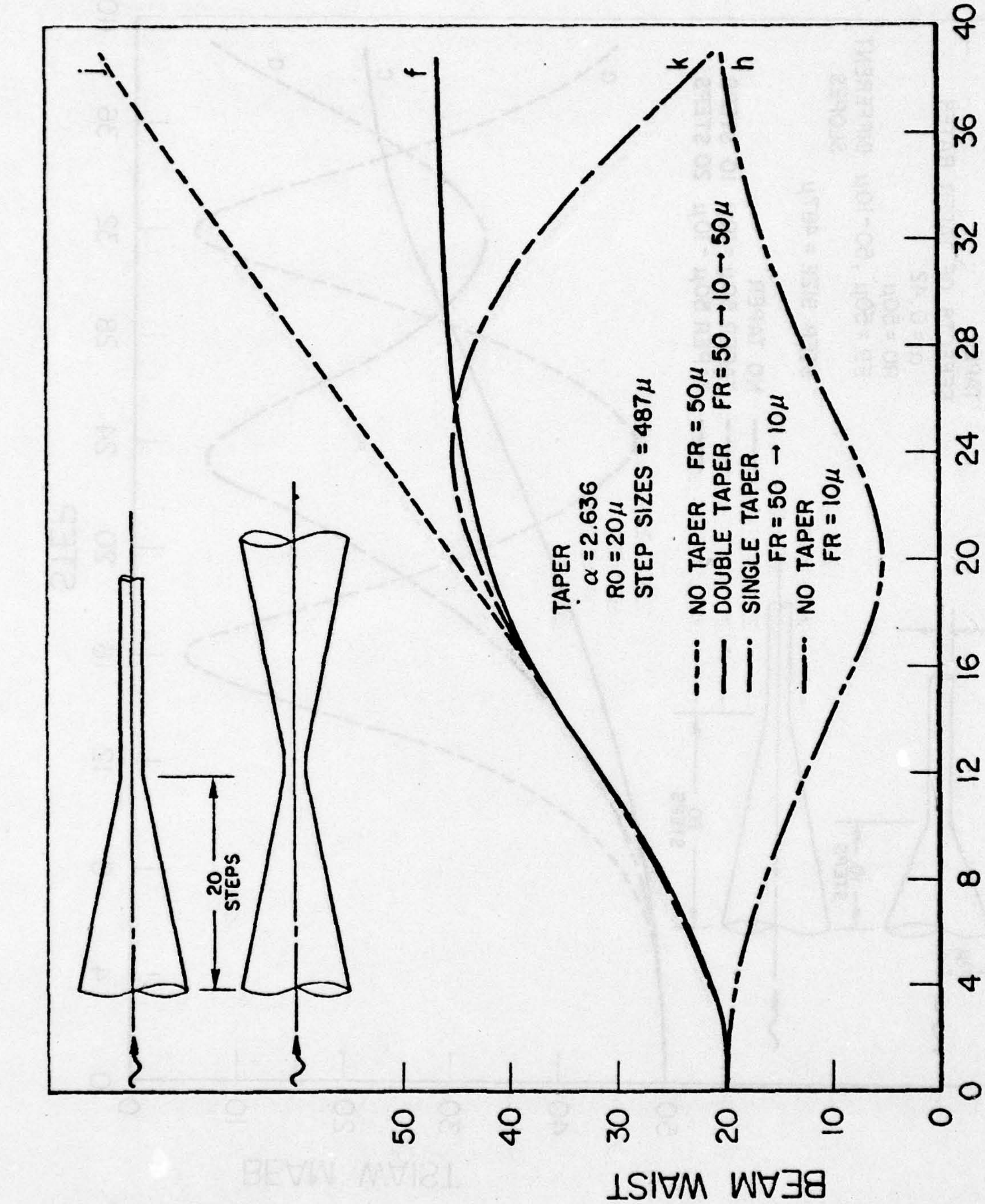
(c) Fiber Horns and Branching Waveguides.

Numerical computations to obtain the field behavior in a



TAPER
EFFECTS OF TAPER RATES
α = 0.42
RO = 50μ
FR = 50μ , 50 - 10μ DIFFERENT SLOPES
STEP SIZE = 487μ
NO TAPER
TAPER 50μ - 10μ 10 STEPS
TAPER 50μ - 10μ 20 STEPS
50μ
10μ
10 STEPS
20 STEPS
a
c
a
BEAM WAIST
STEP
0
10
20
30
40
50
0
4
8
12
16
20
24
28
32
36
40

Figure 6



20 STEPS
TAPER
α = 2.636
RO = 20μ
STEP SIZES = 487μ
NO TAPER FR = 50μ
DOUBLE TAPER FR = 50 → 10 → 50μ
SINGLE TAPER
FR = 50 → 10μ
NO TAPER
FR = 10μ
j
f
k
h
BEAM WAIST
STEP
0
10
20
30
40
50
4
8
12
16
20
24
28
32
36
40

Figure 7

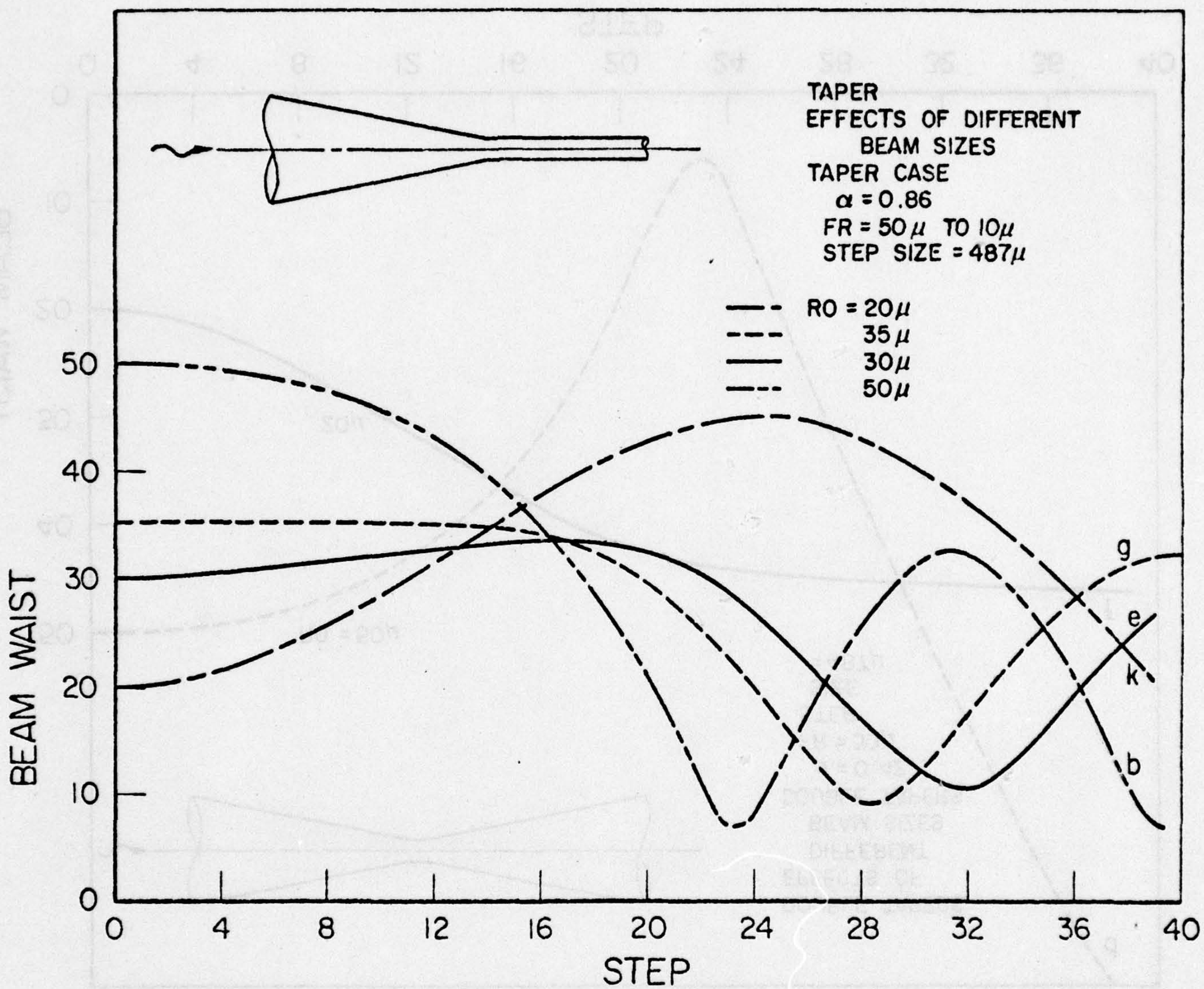

TAPER
EFFECTS OF DIFFERENT
BEAM SIZES
TAPER CASE
α = 0.86
FR = 50μ TO 10μ
STEP SIZE = 487μ
RO = 20μ
35μ
30μ
50μ
g
e
k
b
BEAM WAIST
STEP
0
10
20
30
40
50
4
8
12
16
20
24
28
32
36
40

Figure 8

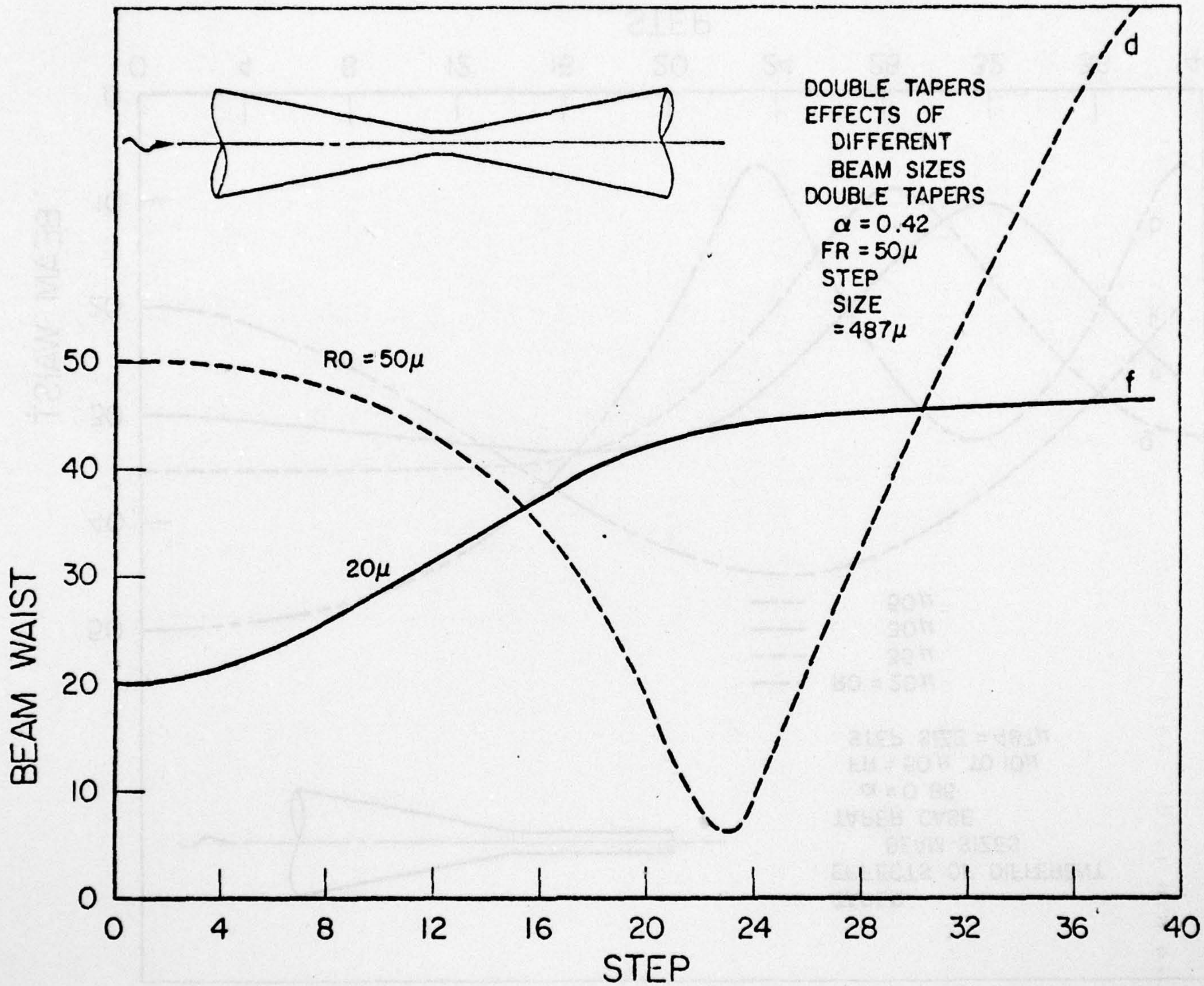

DOUBLE TAPERS
EFFECTS OF
DIFFERENT
BEAM SIZES
DOUBLE TAPERS
α = 0.42
FR = 50μ
STEP
SIZE
= 487μ
RO = 50μ
20μ
d
f
BEAM WAIST
STEP
0
10
20
30
40
50
4
8
12
16
20
24
28
32
36
40

Figure 9

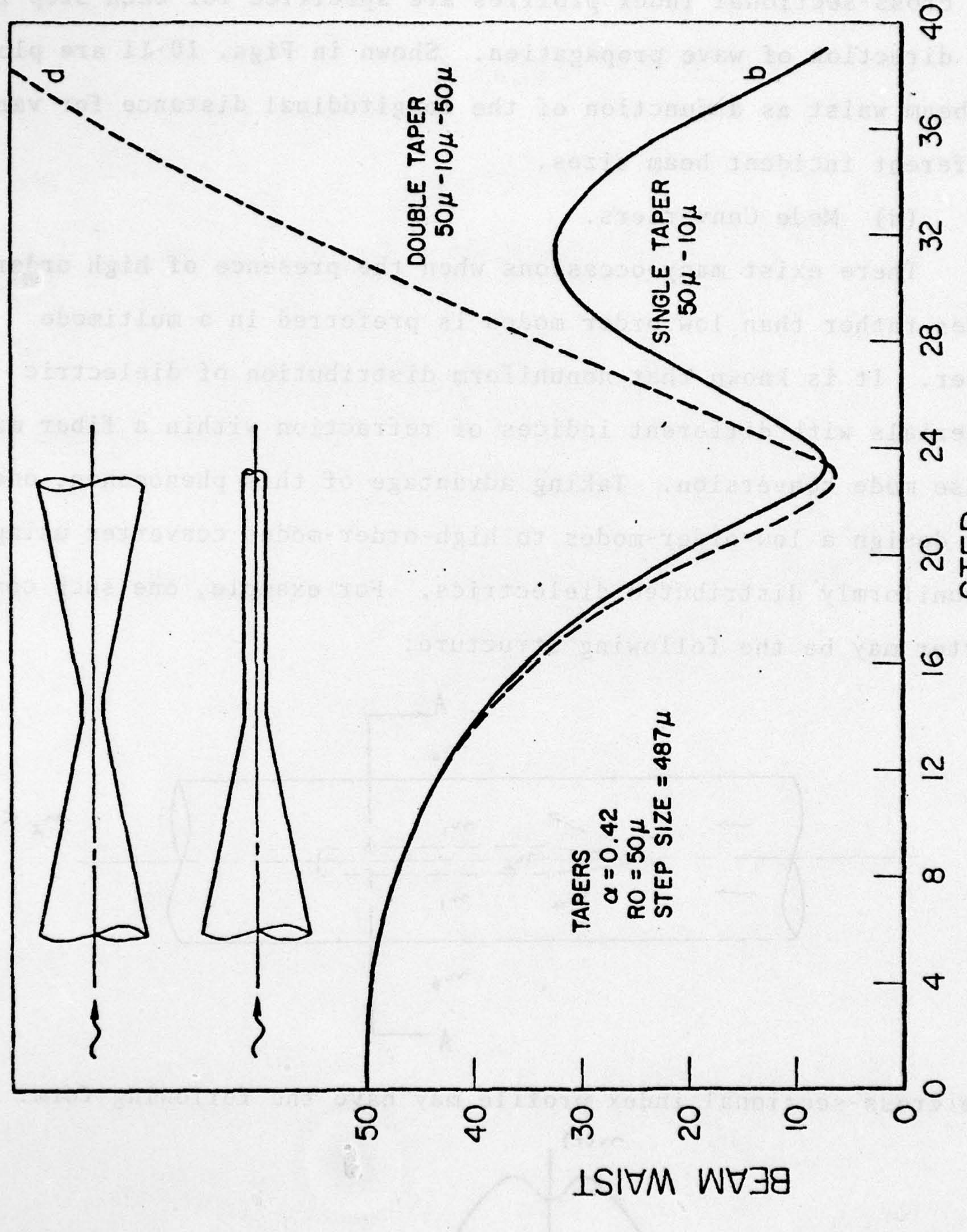
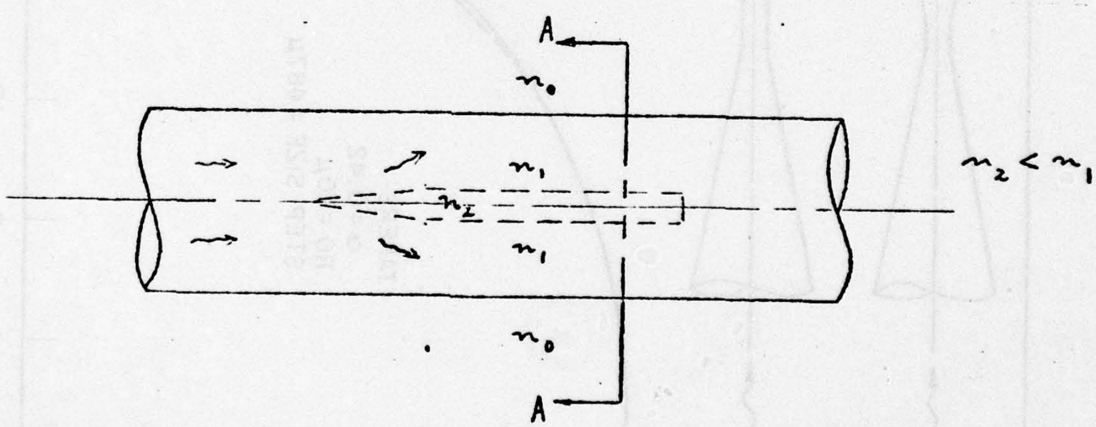

DOUBLE TAPER
50μ - 10μ - 50μ
SINGLE TAPER
50μ - 10μ
TAPERS
α = 0.42
RO = 50μ
STEP SIZE = 487μ
d
b
BEAM WAIST
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
40
STEP

Figure 10

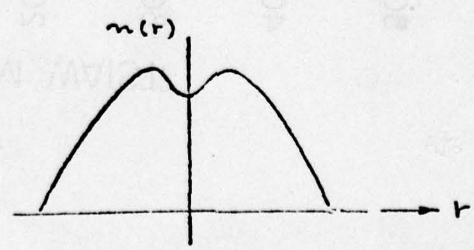
multimode fiber horn structure or in a branching fiber guide have also been carried out using the similar technique outlined earlier. The cross-sectional index profiles are specified for each step in the direction of wave propagation. Shown in Figs. 10-11 are plots of beam waist as a function of the longitudinal distance for various different incident beam sizes.

(d) Mode Converters.

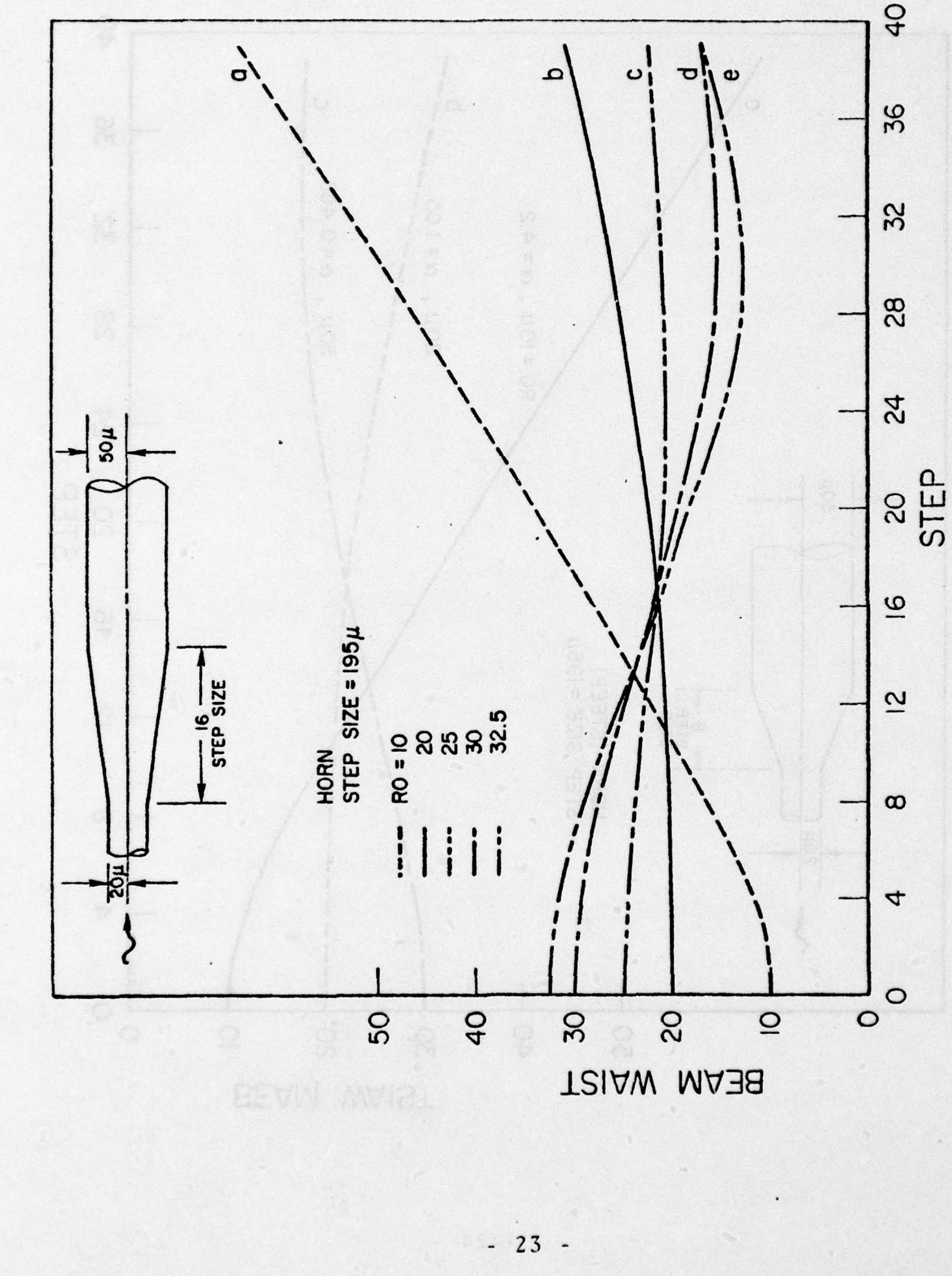
There exist many occasions when the presence of high order modes rather than low order modes is preferred in a multimode fiber. It is known that nonuniform distribution of dielectric materials with different indices of refraction within a fiber may cause mode conversion. Taking advantage of this phenomenon, one may design a low-order-modes to high-order-modes converter using nonuniformly distributed dielectrics. For example, one such converter may be the following structure:



The cross-sectional index profile may have the following form:



Section A-A



50μ
20μ
16 STEP SIZE
HORN
STEP SIZE = 195μ
RO = 10
20
25
30
32.5
a
b
c
d
e
BEAM WAIST
STEP
0
10
20
30
40
50
0
4
8
12
16
20
24
28
32
36
40

Figure 11

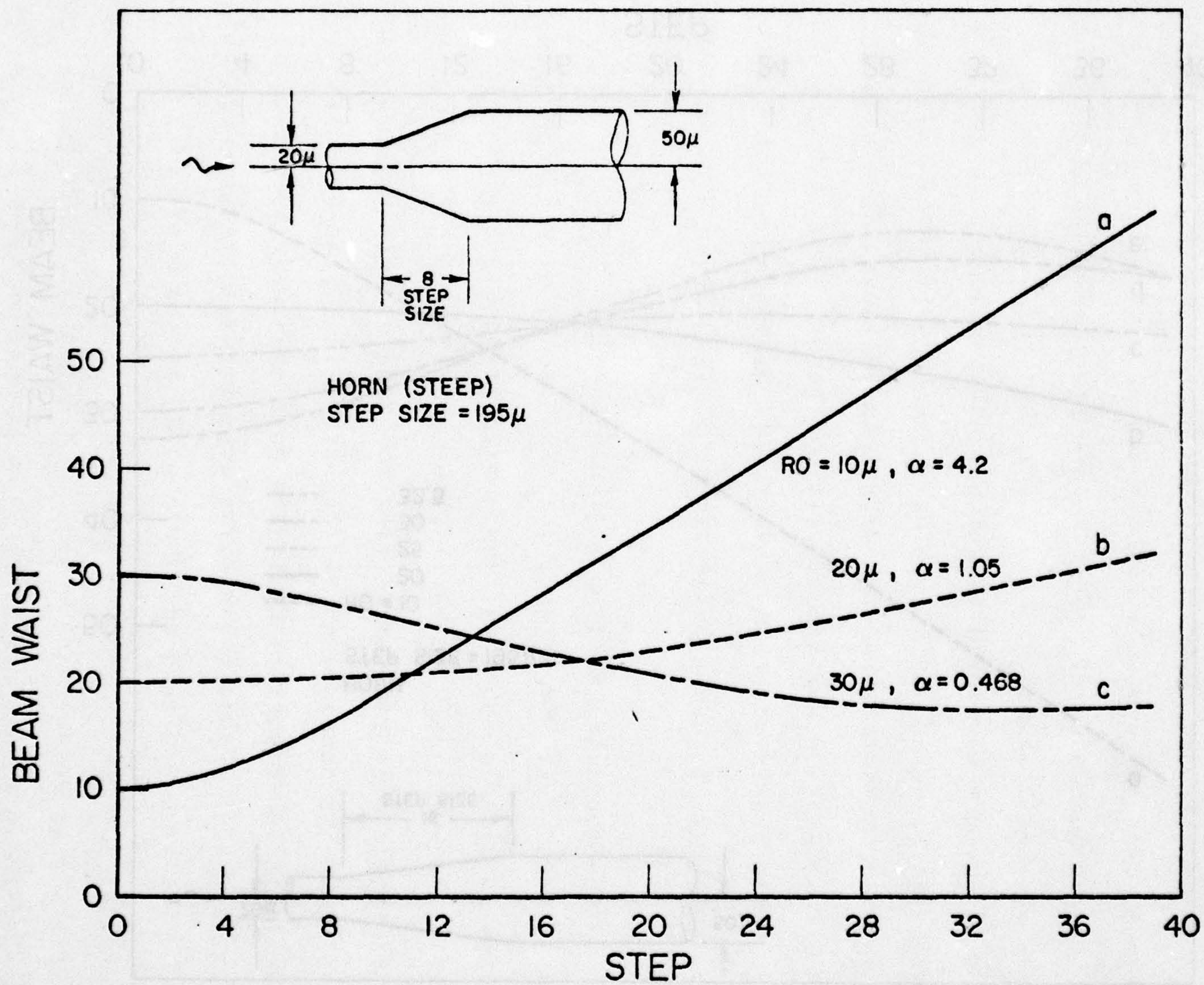

20μ
50μ
8
STEP
SIZE
HORN (STEEP)
STEP SIZE = 195μ
a
RO = 10μ , α = 4.2
b
20μ , α = 1.05
30μ , α = 0.468
c
BEAM WAIST
STEP
0
10
20
30
40
50
0
4
8
12
16
20
24
28
32
36
40

Figure 12

It is anticipated that the low order modes will be affected more by the discontinnuities. Thus energy in the low order modes may be converted into that of the high order modes as expected. Other means of generating high order modes using variations of the above scheme may also be envisioned.

To evaluate the efficiency of this type of mode converter, and to learn the intensity distribution of the resultant field, the evolution of an incident beam through this channel should be obtained. We have successfully developed a program which is capable of providing such information. Illustrative example is given in Appendix C. It can be seen that ring-shaped higher order modes can easily be generated by the introduction of a slight dip in the index profile as proposed above.

IV. Conclusions and Recommendations for Future Work

We have successfully developed a computational technique, based on the scalar wave - FFT method, to treat problems dealing with various multimode fiber components, such as, fiber couplers, fiber tapers or horns, fiber branches or mode converters. The only significant restriction to keep in mind is that index variations of the structure under consideration must be gentle[8]. This consideration is normally satisfied in most practical situations. The basic objective of this R & D study is, thereby accomplished. Listing of the computer program is given in the Appendix. By simply specifying the index profile at each longitudinal z-step and knowing the initial beam shape, one may generate the propagation characteristics of the beam as it propagates down the structure.

Using this program, we were able to trace the evolution of

a given beam as it propagates down a given multimode graded index fiber structure. If the multimode structure were a multimode coupler made with two or more paralled graded index fibers in close proximity of each other, we can predict the coupling distances as well as the power distribution of the beam in such coupler; if the structure were a tapered or a flared multimode fiber, we were able to learn whether a given tapered structure or a given horn structure could still confine or guide a given beam; if the structure were a mode converter made with multimode fiber containing an on-axis dip in its index profile, we can learn the effectiveness of such a dip in converting lower order modes to higher order modes. To achieve such capabilities, an extensive amount of computer software was developed.

In the course of these studies, a number of important new research topics were generated. For example, it is known that the FFT scalar wave approach requires that the index profile be gently varying. But the quantitative definition of "gently" must still be specified. (We wish to push our ability to deal with almost step-index profile fibers.) Initial indication (through our computer results) seem to show that even with rather steep index gradient, adequately accurate results were still obtainable. This problem also leads to the need for us to study the possible usage of adaptive coordinates to improve the beam resolution as it propagates down the multimode structure. Another problem which is directly related to the case of induced beam radiation caused by variations in the guiding structure is also of great interest. Perhaps the

introduction of a lossy surface for the outer boundary of our computer mesh may provide a means of estimating the radiation loss. Associated with beam radiation problem in the case of beam reflection caused by variations in the guiding structure, the reflection coefficient may be obtained by correctly summing over incremental reflection coefficients (i.e., taking into account the phases of the reflected waves) which occur whenever wave energy propagates from a region with a certain index value to another region with a different index value.

With the help of our newly developed program, the principal thrust of the future work should be to study realistic multimode fiber structures, such as data-bus type multi-channel couplers, tapered or flared transition joints, multimode fibers with non-ideal parabolic index profiles and to obtain data for these realistic situations.

Personnel:

The principal contributors of this contract have been:

C. Yeh	Senior Research Engineer
K. Casey	Senior Research Engineer
F. Manshadi	Research Engineer
S. Chang	Research Engineer

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Appendix A

Fiber Coupler

2 Unequal fiber Coupler (50, 25)


```
      PROGRAM OPTFIB(INPUT,OUTPUT,FILE0,TAPE5=INPUT,TAPE6=OUTPUT,          OPTFI
     + TAPE7=FILE0)                                                        OPTFI
C**********************************************************************   OPTFI
C     INPUT PARAMETERS                                                     OPTFI
C CARD 1 (I5 FORMAT)                                                       OPTFI
C     NCASES  NUMBER OF CASES TO BE READ                                   OPTFI
C CARD 2 (NAMELIST FORMAT-$DFAULT $                                        OPTFI
C     LAMBDA  WAVE LENGTH (MICRONS)                                        OPTFI
C     RO      1/E POINT IN IRRADIANCE (MICRONS)                            OPTFI
C     FR      FIBER RADIUS (MICRONS)                                       OPTFI
C     NO      REFRACTIVE INDEX                                             OPTFI
C     PCDRP   PERCENT DROP AT R=FR OF N/NO                                 OPTFI
C     OUTRAD  OUTER RADIUS (MICRONS)                                       OPTFI
C     DX      MESH SPACING (MICRONS)                                       OPTFI
C     NSTEPS  NUMBER OF Z-STEPS                                            OPTFI
C     NDZINC  LENGTH OF Z-STEP = ZMIN/NDZINC                               OPTFI
C     IOUT    DEVICE NUMBER FOR OUTPUT                                     OPTFI
C     IGREY   DEVICE NUMBER FOR GREYSC OUTPUT                              OPTFI
C     PGREY   IF TRUE PRINT IRRADIANCE PROFILE AT EACH STEP                OPTFI
C     PWAIST  IF TRUE WRITE 2ND MOMENTS AT EACH STEP                       OPTFI
C     PLTWST  IF TRUE PLOT 2ND MOMENTS VS DISTANCE                         OPTFI
C     PLTMAX  IF TRUE PLOT PEAK INTENSITY VS DISTANCE                      OPTFI
C     PLTFLD  IF TRUE PLOT FIELD IRRAD AT END OF PROPAGATION ALONG I       OPTFI
C     PLTFLE  IF TRUE DO ABOVE PLOT AT EVERY STEP                          OPTFI
C     MESH    GRID SIZE (32, 64, OR 128)                                   OPTFI
C**********************************************************************   OPTFI
C                                                                          OPTFI
      COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZTSQ(128),POSQ(128)      LCM2
     + ,AMPARY(16384),RADARY(16384)                                        LCM2
      LEVEL 2,REFNDX,SN,CS,ZTSQ,POSQ,AMPARY,RADARY                         LCM2
      DIMENSION WORK(256),MU(2)                                            OPTF
      DIMENSION X0(3),Y0(3),PCDRPA(3),FRA(3),REFCFA(3)                     TEMP
      COMMON  /ARRAYS/V(32768)                                             ARRA
      COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PCDRP,OUTRAD,DX,NSTEPS,     PARA
     + NDZINC,MESHSQ,MSHSQ2,PI,WAVENM,DXSI,MS,NS,MF,NF,MSHPTS              PARA
      COMMON /PRNTPLT/PGREY,PWAIST,PLTWST,PLTMAX,LAST,IOUT,IGREY           PRNT
     + ,PLTFLD,PLTFLE                                                      PRNT
C                                                                          OPTF
      REAL LAMBDA,NO,NOSQ,N2                                               OPTF
      LOGICAL PGREY,PWAIST,PLTWST,PLTMAX,PLTFLD,PLTFLE,LAST,CALLPR         OPTF
C                                                                          OPTF
      DATA PI/3.141592657,ICNTCS/17,ICNT/07                                OPTF
C                                                                          OPTF
      NAMELIST /DFAULT/LAMBDA,RO,FR,NO,PCDRP,OUTRAD,DX,NSTEPS,NDZINC,      OPTF
     + IOUT,IGREY,PGREY,PWAIST,PLTWST,PLTMAX,PLTFLD,PLTFLE,MESH             OPTF
C                                                                          OPTF
      READ(5,1000) NCASES                                                  OPTF
      READ(5,*) XB,YB                                                      TEMP
      READ(5,1000) NFIB                                                    TEMP
      READ(5,*) (X0(I),Y0(I),I=1,NFIB)                                     TEMP
      WRITE(6,*) (X0(I),Y0(I),I=1,NFIB)                                    TEMP
      READ(5,*) (PCDRPA(K),K=1,NFIB)                                       TEMP
      READ(5,*) (FRA(K),K=1,NFIB)                                          TEMP
      WRITE(6,*) (PCDRPA(K),K=1,NFIB)                                      TEMP
      WRITE(6,*) (FRA(K),K=1,NFIB)                                         TEMP
 1000 FORMAT(I5)                                                           OPTF
    1 READ(5,DFAULT)                                                       OPTF
```

```
C                                                                       OPTFIB
      ICNT=0                                                            OPTFIB
      FLAG=NO/ABS(NO)                                                   OPTFIB
      NO=ABS(NO)                                                        OPTFIB
      IF(FLAG.LT.0.) WRITE(IOUT,2050)                                   OPTFIB
 2050 FORMAT(/,47H THE REFRACTIVE INDEX IS A CONSTANT EQUAL TO NO)      OPTFIB
      PCDRP=PCDRPA(1)                                                   TEMP
      FR=FRA(1)                                                         TEMP
      WRITE(IOUT,DFAULT)                                                OPTFIB
C                                                                       OPTFIB
C     CALCULATE CONSTANTS                                               OPTFIB
C                                                                       OPTFIB
      MESH2=2*MESH                                                      OPTFIB
      MESHSQ=MESH**2                                                    OPTFIB
      MSHSQ2=2*MESHSQ                                                   OPTFIB
      RN2NO=.02*PCDRP/FR**2                                             OPTFIB
      ZMIN=PI/(2.*SQRT(RN2NO))                                          OPTFIB
      DZINC=ZMIN/NDZINC                                                 OPTFIB
      DXSI=DZINC/ZMIN                                                   OPTFIB
      DXSIH=DXSI/2.                                                     OPTFIB
      DZET=DX/RO                                                        OPTFIB
      WAVENM=2.*PI/LAMBDA                                               OPTFIB
      BETAHT=(2.*ZMIN*DXSI/(WAVENM*NO))*(PI/(MESH*DZET*RO))**2          OPTFIB
      FTCNST=(1.-1./MESH)*PI                                            OPTFIB
      XYO=MESH/2.                                                       OPTFIB
      RADNRM=(OUTRAD/RO)**2                                             OPTFIB
      RNORM=1./MESHSQ                                                   OPTFIB
      N2=NO*RN2NO                                                       OPTFIB
      REFCF=N2*RO**2/2.                                                 OPTFIB
      ALPHA=2.*ZMIN/(PI*WAVENM*NO*RO**2)                                OPTFIB
      NOSQ=NO**2                                                        OPTFIB
      MU(1)=MESH                                                        OPTFIB
      MU(2)=MESH                                                        OPTFIB
      XSIMUL=DXSI                                                       OPTFIB
      LAST=.F.                                                          OPTFIB
      IF(FLAG.LT.0.) REFCF=0.                                           OPTFIB
      CALLPR=PGREY.OR.PWAIST.OR.PLTWST.OR.PLTMAX.OR.PLTFLD.OR.PLIFLE    OPTFIB
C                                                                       OPTFIB
C     WRITE THE IMPORTANT CALCULATED PARAMETERS                         OPTFIB
C                                                                       OPTFIB
      WRITE(IOUT,2000) ZMIN,DZINC,RN2NO,ALPHA                           OPTFIB
 2000 FORMAT(/,8H ZMIN = ,F10.4,1X,7HMICRONS,/,9H DZINC = ,F10.4,1X,    OPTFIB
     + 7HMICRONS,/,9H RN2NO = ,E10.3,1X,13HMICRONS**(-2),/,             OPTFIB
     + 9H ALPHA = ,F10.5,/)                                             OPTFIB
C                                                                       OPTFIB
C     CALCULATE NECESSARY ARRAYS                                        OPTFIB
C                                                                       OPTFIB
      DO 800 K=1,NFIB                                                   TEMP
      XO(K)=XO(K)+XYO                                                   TEMP
      YO(K)=YO(K)+XYO                                                   TEMP
      REFCFA(K)=NO*.02*PCDRPA(K)*(RO/FRA(K))**2/2.                      TEMP
  800 CONTINUE                                                          TEMP
      DO 100 K=1,MESH                                                   OPTFIB
      RK=K-1                                                            OPTFIB
      ARG=FTCNST*RK                                                     OPTFIB
      CS(K)=COS(ARG)                                                    OPTFIB
      SN(K)=SIN(ARG)                                                    OPTFIB
```

```
      ZTSQ(K)=((RK-XYO)*DZET)**2                                         OPTFIB
      PQSQ(K)=(RK-XYO+.5)**2                                             OPTFIB
  100 CONTINUE                                                           OPTFIB
C                                                                        OPTFIB
C     SET UP REFRACTIVE INDEX ARRAY                                      OPTFIB
C                                                                        OPTFIB
      M=0                                                                OPTFIB
      DO 120 J=1,MESH                                                    OPTFIB
      DO 120 I=1,MESH                                                    TEMP
      M=M+1                                                              TEMP
      TMPNDX=0.                                                          TEMP
      DO 110 K=1,NFIB                                                    TEMP
      Z1=((J-1.-YO(K))*DZET)**2                                          TEMP
      Z2=((I-1.-XO(K))*DZET)**2                                          TEMP
      RAD=Z1+Z2                                                          TEMP
      TMPNDX=AMAX1(TMPNDX,(NO-REFCFA(K)*RAD))                            TEMP
  110 CONTINUE                                                           TEMP
      REFNDX(M)=AMAX1(TMPNDX,1.)                                         TEMP
C     IF(I.EQ.52.OR.I.EQ.58) WRITE(IOUT,*) REFNDX(M)                     TEMP
  120 CONTINUE                                                           OPTFIB
      IF(MESH.NE.128) GO TO 10                                           OPTFIB
      MS=MESH/4+1                                                        OPTFIB
      MF=MS+MESH/2-1                                                     OPTFIB
      NS=MS                                                              OPTFIB
      NF=MF                                                              OPTFIB
      GO TO 40                                                           OPTFIB
   10 CONTINUE                                                           OPTFIB
      MS=1                                                               OPTFIB
      NS=1                                                               OPTFIB
      MF=MESH                                                            OPTFIB
      NF=MESH                                                            OPTFIB
   40 CONTINUE                                                           OPTFIB
      DO 130 K=1,MESHSQ                                                  OPTFIB
      REFNDX(K)=REFNDX(K)**2-NUSQ                                        OPTFIB
  130 CONTINUE                                                           OPTFIB
      CALL GREYSC(IGREY,10,REFNDX,MESH,MESH,MS,MF,1,NS,NF,1,0.,0.,      TEMP
     + 6HREFNDX,5)                                                       TEMP
C                                                                        OPTFIB
C     SET UP INITIAL FIELD                                               OPTFIB
C                                                                        OPTFIB
      M=-1                                                               OPTFIB
      K=0                                                                OPTFIB
      CH=WAVENM*ZMIN*DXSIH/(2.*NO)                                       OPTFIB
      DO 140 J=1,MESH                                                    OPTFIB
      Z1=((J-XYO-YB-1)*DZET)**2                                          TEMP
      DO 140 I=1,MESH                                                    OPTFIB
      K=K+1                                                              OPTFIB
      M=M+2                                                              OPTFIB
      MP1=M+1                                                            OPTFIB
      Z2=((I-XYO-XB-1)*DZET)**2                                          TEMP
      RAD=Z1+Z2                                                          OPTFIB
      IF(RAD.GT.RADNRM) GO TO 20                                         OPTFIB
      AMP=EXP(-RAD/2.)                                                   OPTFIB
      ARG=CH*REFNDX(K)                                                   OPTFIB
      V(M)=AMP*COS(ARG)                                                  OPTFIB
      V(MP1)=AMP*SIN(ARG)                                                OPTFIB
      GO TO 140                                                          OPTFIB
```

```
 20   CONTINUE                                                          OPTFI8
      V(M)=0.                                                           OPTFI8
      V(MP1)=0.                                                         OPTFI8
 140  CONTINUE                                                          OPTFI8
      IF(CALLPR) CALL PRNTER(ICNT)                                      OPTFI8
C                                                                       OPTFI8
C     DO PROPAGATION                                                    OPTFI8
C                                                                       OPTFI8
      DO 500 ICNT=1,NSTEPS                                              OPTFI8
C                                                                       OPTFI8
C     CONDITION V FOR TRANSFORM                                         OPTFI8
C                                                                       OPTFI8
      K=-1                                                              OPTFI8
      DO 160 J=1,MESH                                                   OPTFI8
      SNJ=SN(J)                                                         OPTFI8
      CSJ=CS(J)                                                         OPTFI8
      DO 160 I=1,MESH                                                   OPTFI8
      K=K+2                                                             OPTFI8
      KP1=K+1                                                           OPTFI8
      SNI=SN(I)                                                         OPTFI8
      CSI=CS(I)                                                         OPTFI8
      AR=CSJ*CSI-SNJ*SNI                                                OPTFI8
      AI=-(CSJ*SNI+CSI*SNJ)                                             OPTFI8
      VR=V(K)                                                           OPTFI8
      VI=V(KP1)                                                         OPTFI8
      V(K)=VR*AR-VI*AI                                                  OPTFI8
      V(KP1)=VI*AR+VR*AI                                                OPTFI8
 160  CONTINUE                                                          OPTFI8
C                                                                       OPTFI8
C     DO TRANSFORM                                                      OPTFI8
C                                                                       OPTFI8
      CALL FOURT(V,MU,2,1,1,WORK)                                       OPTFI8
C                                                                       OPTFI8
C     SOLVE FIRST ORDER ODE                                             OPTFI8
C                                                                       OPTFI8
      K=-1                                                              OPTFI8
      DO 180 J=1,MESH                                                   OPTFI8
      PHI1=BETAHT*POSQ(J)                                               OPTFI8
      DO 180 I=1,MESH                                                   OPTFI8
      K=K+2                                                             OPTFI8
      KP1=K+1                                                           OPTFI8
      PHI2=BETAHT*POSQ(I)                                               OPTFI8
      VR=V(K)                                                           OPTFI8
      VI=V(KP1)                                                         OPTFI8
      ANG=-(PHI1+PHI2)                                                  OPTFI8
      CANG=COS(ANG)                                                     OPTFI8
      SANG=SIN(ANG)                                                     OPTFI8
      V(K)=(VR*CANG-VI*SANG)*RNORM                                      OPTFI8
      V(KP1)=(VR*SANG+VI*CANG)*RNORM                                    OPTFI8
 180  CONTINUE                                                          OPTFI8
C                                                                       OPTFI8
C     DO INVERSE TRANSFORM                                              OPTFI8
C                                                                       OPTFI8
      CALL FOURT(V,MU,2,-1,1,WORK)                                      OPTFI8
C                                                                       OPTFI8
C     RECONDITION V BECAUSE OF TRANSFORM                                OPTFI8
C                                                                       OPTFI8
```

```
      K=-1                                                          OPTFIB
      DO 200 J=1,MESH                                               OPTFIB
      SNJ=SN(J)                                                     OPTFIB
      CSJ=CS(J)                                                     OPTFIB
      DO 200 I=1,MESH                                               OPTFIB
      K=K+2                                                         OPTFIB
      KP1=K+1                                                       OPTFIB
      SNI=SN(I)                                                     OPTFIB
      CSI=CS(I)                                                     OPTFIB
      AR=CSJ*CSI-SNJ*SNI                                            OPTFIB
      AI=CSJ*SNI+SNJ*CSI                                            OPTFIB
      VR=V(K)                                                       OPTFIB
      VI=V(KP1)                                                     OPTFIB
      V(K)=VR*AR-VI*AI                                              OPTFIB
      V(KP1)=VR*AI+VI*AR                                            OPTFIB
  200 CONTINUE                                                      OPTFIB
C                                                                   OPTFIB
C     NOW INCLUDE EITHER FULL STEP OR HALF STEP REFRACTIVE          OPTFIB
C     INDEX EFFECTS DEPENDING ON WHERE IN THE PATH YOU ARE          OPTFIB
C                                                                   OPTFIB
      IF(ICNT.EQ.NSTEPS) XSIMUL=DXSIH                               OPTFIB
      K=-1                                                          OPTFIB
      CH=WAVENM*ZMIN*XSIMUL/(2.*NO)                                 OPTFIB
      DO 220 M=1,MESHSQ                                             OPTFIB
      ARG=REFNDX(M)*CH                                              OPTFIB
      AR=COS(ARG)                                                   OPTFIB
      AI=SIN(ARG)                                                   OPTFIB
      K=K+2                                                         OPTFIB
      KP1=K+1                                                       OPTFIB
      VR=V(K)                                                       OPTFIB
      VI=V(KP1)                                                     OPTFIB
      V(K)=VR*AR-VI*AI                                              OPTFIB
      V(KP1)=VR*AI+VI*AR                                            OPTFIB
  220 CONTINUE                                                      OPTFIB
      IF(ICNT.EQ.NSTEPS) LAST=.T.                                   OPTFIB
      IF(CALLPR) CALL PRNTER(ICNT)                                  OPTFIB
  500 CONTINUE                                                      OPTFIB
C                                                                   OPTFIB
C     CALCULATE IRRADIANCE PATTERN AND PRINT                        OPTFIB
C                                                                   OPTFIB
      IF(PGREY) GO TO 30                                            OPTFIB
      M=0                                                           OPTFIB
      DO 240 K=1,MSHSQ2,2                                           OPTFIB
      KP1=K+1                                                       OPTFIB
      VR=V(K)                                                       OPTFIB
      VI=V(KP1)                                                     OPTFIB
      M=M+1                                                         OPTFIB
      RADARY(M)=VR**2+VI**2                                         OPTFIB
  240 CONTINUE                                                      OPTFIB
      CALL GREYSC(IGREY,10,RADARY,MESH,MESH,MS,MF,1,NS,NF,1,0.,0.,  OPTFIB
     + 10HIRRADIANCE,10)                                            OPTFIB
   30 CONTINUE                                                      OPTFIB
      ICNTCS=ICNTCS+1                                               OPTFIB
      IF(ICNTCS.LE.NCASES) GO TO 1                                  OPTFIB
      END                                                           OPTFIB
```

```
      SUBROUTINE PEAK(VMAX)                                                  PEAK
      COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZISQ(128),PQSQ(128)         LCM2
     + ,AMPARY(16384),RADARY(16384)                                          LCM2
      LEVEL 2,REFNDX,SN,CS,ZISQ,PQSQ,AMPARY,RADARY                           LCM2
      COMMON  /ARRAYS/V(32768)                                               ARRAYS
      COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PCDRP,OUTRAD,DX,NSTEPS,       PARAM
     + NDZINC,MESHSQ,MSHSQ2,PI,WAVENM,DXSI,MS,NS,MF,NF,MSHPTS                PARAM
      L=0                                                                    PEAK
      SUML=0.                                                                TEMP
      SUMR=0.                                                                TEMP
      VMAX=0.                                                                PEAK
      DO 10 K=1,MSHSQ2,2                                                     PEAK
      VR=V(K)                                                                PEAK
      L=L+1                                                                  PEAK
      KP1=K+1                                                                PEAK
      VI=V(KP1)                                                              PEAK
      VRAD=VI**2+VR**2                                                       PEAK
      IF(K.LE.MESHSQ) SUML=SUML+VRAD                                         TEMP
      IF(K.GT.MESHSQ) SUMR=SUMR+VRAD                                         TEMP
      VMAX=AMAX1(VMAX,VRAD)                                                  PEAK
      RADARY(L)=VRAD                                                         PEAK
   10 CONTINUE                                                               PEAK
      TOT=SUML+SUMR                                                          TEMP
      SUML=SUML/TOT                                                          TEMP
      SUMR=SUMR/TOT                                                          TEMP
      WRITE(6,2000) SUML,SUMR                                                TEMP
 2000 FORMAT(/,1X,7HSUML = ,E14.7,3X,7HSUMR = ,E14.7,/)                     TEMP
      RETURN                                                                 PEAK
      END                                                                    PEAK
```

CFERENCE MAP (R=1)

TYPE		RELOCATION					
REAL	ARRAY	LCM2	40200	CS	REAL	ARRAY	LCM2
REAL		PARAM	17	DXSI	REAL		PARAM
REAL		PARAM	4	FR	REAL		PARAM
INTEGER			51	KP1	INTEGER		
INTEGER			2	LAMBDA	INTEGER		PARAM
INTEGER		PARAM	13	MESHSQ	INTEGER		PARAM
INTEGER		PARAM	20	MS	INTEGER		PARAM
INTEGER		PARAM	14	MSHSQ2	INTEGER		PARAM
INTEGER		PARAM	23	NF	INTEGER		PARAM
INTEGER		PARAM	21	NS	INTEGER		PARAM
INTEGER		PARAM	7	OUTRAD	REAL		PARAM
REAL		PARAM	15	PI	REAL		PARAM
REAL	ARRAY	LCM2	101000	RADARY	REAL	ARRAY	LCM2
REAL	ARRAY	LCM2	3	RO	REAL		PARAM
REAL	ARRAY	LCM2	45	SUML	REAL		
REAL			54	TOT	REAL		
REAL	ARRAY	ARRAYS	52	VI	REAL		

```
      SUBROUTINE GREYSC(IFILE1,NLEVEL,AMAT,IDIM,JDIM,IMIN,IMAX,IDEL,
     +  JMIN,JMAX,JDEL,AMIN,AMAX,TITLE,NCHAR)
      LEVEL 2,AMAT
      DIMENSION ICHARS(10,3),LINE(132,3),LEVEL(10),AMAT(IDIM,JDIM)
      DIMENSION TITLE(20)
      DATA ICHARS/1H ,1H.,1H-,1H+,1H*,60606060606060606060,1H*,3*1HO
     + ,6*1H ,1HX,1H+,2*60606060606060606060,9*1H ,1H*/
      DATA IBORDR/1H*/,IBLANK/1H /
      DATA LEVEL/6*1,3*2,3/
      DATA NCPW/10/
      DATA NLMAX /59/
      IFILEX=-IFILE1
C-----------------------------------------------------------------------
C
C                               GREYSC
C
C PURPOSE--PRODUCES A SHADED (GREY-SCALE) LINE PRINTER PLOT OF
C          A TWO-DIMENSINAL, REAL MATRIX.
C
C USAGE--CALL GREYSC(IFILE,NLEVEL,AMAT,IDIM,JDIM,IMIN,IMAX,IDEL,
C        JMIN,JMAX,JDEL,AMIN,AMAX,TITLE,NCHAR)
C   IFILEX (OUTPUT FILE CODE..+ FOR LBL, - FOR OTHER SYSTEMS OR TERMINAL
C   NLEVEL (NO. OF GREY-LEVELS TO BE PRINTED)
C   AMAT (THE 2D MATRIX TO BE DISPLAYED)
C   IDIM (THE FIRST DIMENSION OF MATRIX AMAT)
C   JDIM (THE SECOND DIMENSION OF MATRIX AMAT)
C   IMIN (THE BEGINNING I-COORDINATE FOR THE PLOT)
C   IMAX (THE ENDING I-COORDINATE FOR THE PLOT)
C   IDEL (USED IN THE SENSE ...I=IMIN,IMAX,IDEL)
C   JMIN,JMAX,JDEL (SEE IMIN,IMAX, AND IDEL DESCRIPTIONS)
C   AMIN (THE MINIMUM VALUE USED FOR SCALING--SEE BELOW)
C   AMAX (THE MAXIMUM VALUE USED FOR SCALING--SEE BELOW)
C   TITLE (CHARACTER VECTOR OR HOLLERITH STRING FOR TITLE)
C   NCHAR (NO. OF CHARACTERS IN TITLE VECTOR)
C
C SUBPROGRAM REFERENCES--(NONE)
C
C COMMENTS--
C    1. CREATED 7/2/74 BY C. SOUTH
C    2. NLEVEL CAN BE NO LARGER THAN 10.  IF =5, CHARACTERS
C       ARE NOT OVERPRINTED.  IF BETWEEN 6 AND 9, CHARACTERS WILL BE
C       OVERPRINTED NO MORE THAN ONCE.  IF =10, THE DENSEST CHARACTER
C       WILL BE OVERPRINTED TWICE.
C    3. SCALING IS LINEAR BETWEEN AMIN AND AMAX.  IF AMIN=AMAX,
C       SCALING WILL BE AUTOMATICALLY SET TO FULL RANGE FOR THE MATRIX.
C    4. MACHINE COMPATIBILITY--CHANGE VARIABLE NCPW IN DATA STATEMENT
C       TO INDICATE NUMBER OF CHARACTERS PER WORD FOR THE MACHINE.
C    5. PLOT BORDER--DEFAULT IS A BORDER OF ASTERISKS.  TO RESET THE
C       CHARACTER, CHANGE THE VARIABLE IBORDR IN THE DATA STATEMENT
C       (ALGORITHM WILL CORRECTLY HANDLE THE BLANK BORDER CASE).
C    6. CHANGED 7/31/74 TO HANDLE CASE OF 5 CHARS/WORD.
C    7. CHANGED 8/12/74 TO CHANGE SIXTH CHARACTER TO A SIMPLE '*'.
C    8. CHANGED 8/27/74 TO DEFINE CHAR. 5-7 AS (*),(NUM SIGN),(* PLUS X).
C    9. CHANGED 9/12/77 TO ALTER PAGE HANDLING.  THIS ROUTINE WILL NOW
C       TRY TO FIT BOTH THE SCALING INFORMATION AND THE GREYSCALE PLOT
C       ON THE SAME PAGE, WITH SCALING INFORMATION BELOW THE PLOT.
C       NLMAX REPRESENTS THE MAXIMUM ROWS FOR THE INPUT MATRIX STILL
```

```
C         ALLOWING THE SCALING INFORMATION TO APPEAR ON THE SAME PAGE.        GREYSC
C-----------------------------------------------------------------------     GREYSC
C                                                                            GREYSC
C         SCALE, IF NECESSARY                                                GREYSC
C                                                                            GREYSC
          AMX=AMAX                                                           GREYSC
          IFILE=IABS(IFILEX)                                                 GREYSC
          AMN=AMIN                                                           GREYSC
          IF(AMAX.GT.AMIN) GO TO 100                                         GREYSC
          AMN=1.E20                                                          GREYSC
          AMX=-1.E20                                                         GREYSC
          DO 50 I=IMIN,IMAX,IDEL                                             GREYSC
          DO 50 J=JMIN,JMAX,JDEL                                             GREYSC
          AMN=AMIN1(AMN,AMAT(I,J))                                           GREYSC
   50     AMX=AMAX1(AMX,AMAT(I,J))                                           GREYSC
  100     CONTINUE                                                           GREYSC
C                                                                            GREYSC
C         PRINT HEADER                                                       GREYSC
C                                                                            GREYSC
          NWORDS=(NCHAR-1)/NCPW+1                                            GREYSC
          IF(NCPW.EQ.6) WRITE(IFILE,1040) (TITLE(I),I=1,NWORDS)              GREYSC
          IF(NCPW.EQ.4) WRITE(IFILE,1041) (TITLE(I),I=1,NWORDS)              GREYSC
          IF(NCPW.EQ.10) WRITE(IFILE,1042) (TITLE(I),I=1,NWORDS)             GREYSC
          IF(NCPW.EQ.5) WRITE(IFILE,1043) (TITLE(I),I=1,NWORDS)              GREYSC
          IF(AMX.EQ.AMN) RETURN                                              GREYSC
C                                                                            GREYSC
C         PREPARE A LINE FOR PRINTING                                        GREYSC
C                                                                            GREYSC
          LINE(1,1)=IBORDR                                                   GREYSC
          JLOC=(JMAX-JMIN)/JDEL+3                                            GREYSC
          LINE(JLOC+2,1)=IBORDR                                              GREYSC
          LINE(1,2)=IBLANK                                                   GREYSC
          LINE(1,3)=IBLANK                                                   GREYSC
          LINE(JLOC+2,2)=IBLANK                                              GREYSC
          LINE(JLOC+2,3)=IBLANK                                              GREYSC
          LASTLI=JLOC+2                                                      GREYSC
          NLASTL=LASTLI-1                                                    GREYSC
          WRITE(IFILE,1045) (IBORDR,I=1,LASTLI)                              GREYSC
          DO 400 I=IMIN,IMAX,IDEL                                            GREYSC
          DO 250 II=1,3                                                      GREYSC
          DO 250 J=2,NLASTL                                                  GREYSC
  250     LINE(J,II)=IBLANK                                                  GREYSC
          LEV=1                                                              GREYSC
          J=2                                                                GREYSC
          DO 300 JJ=JMIN,JMAX,JDEL                                           GREYSC
          J=J+1                                                              GREYSC
          L=(AMAT(I,JJ)-AMN)/(AMX-AMN)*FLOAT(NLEVEL)+1.                      GREYSC
          L=MAX0(1,L)                                                        GREYSC
          L=MIN0(NLEVEL,L)                                                   GREYSC
          LEV=MAX0(LEV,LEVEL(L))                                             GREYSC
          LEVNOW=LEVEL(L)                                                    GREYSC
          DO 300 K=1,LEVNOW                                                  GREYSC
          LINE(J,K)=ICHARS(L,K)                                              GREYSC
  300     CONTINUE                                                           GREYSC
C                                                                            GREYSC
C         FIND LAST PRINT POSITION                                           GREYSC
C                                                                            GREYSC
```

```
      DO 400 KL=1,LEV                                                   GREYSC
      DO 350 K=1,LASTLI                                                 GREYSC
      KK=LASTLI-K+1                                                     GREYSC
      IF(LINE(KK,KL).NE.IBLANK) GO TO 375                               GREYSC
  350 CONTINUE                                                          GREYSC
  375 CONTINUE                                                          GREYSC
      IF(IFILEX.GT.0.AND.KL.EQ.LEV) WRITE(IFILE,1050) (LINE(II,KL),     GREYSC
     1II=1,KK)                                                          GREYSC
      IF(IFILEX.LT.0.AND.KL.EQ.1) WRITE(IFILE,1050) (LINE(II,KL),       GREYSC
     1 II=1,KK)                                                         GREYSC
      IF(IFILEX.GT.0.AND.KL.NE.LEV) WRITE(IFILE,1060) (LINE(II,KL),     GREYSC
     1 II=1,KK)                                                         GREYSC
      IF(IFILEX.LT.0.AND.KL.NE.1) WRITE(IFILE,1060)  (LINE(II,KL),      GREYSC
     1II=1,KK)                                                          GREYSC
  400 CONTINUE                                                          GREYSC
C                                                                       GREYSC
C     WRITE LAST LINE (BORDER)                                          GREYSC
C                                                                       GREYSC
      WRITE(IFILE,1070) (IBORDR,I=1,LASTLI)                             GREYSC
C                                                                       GREYSC
C   PRINT TRAILING SCALE INFORMATION                                    GREYSC
C                                                                       GREYSC
      IF(NCPW.EQ.6) WRITE(IFILE,1000) (TITLE(I),I=1,NWORDS)             GREYSC
      IF(NCPW.EQ.4) WRITE(IFILE,1001) (TITLE(I),I=1,NWORDS)             GREYSC
      IF(NCPW.EQ.10) WRITE(IFILE,1002) (TITLE(I),I=1,NWORDS)            GREYSC
      IF(NCPW.EQ.5) WRITE(IFILE,1003) (TITLE(I),I=1,NWORDS)             GREYSC
      WRITE(IFILE,1010)                                                 GREYSC
      DELTA=(AMX-AMN)/FLOAT(NLEVEL)                                     GREYSC
      DO 200 I=1,NLEVEL                                                 GREYSC
      XMIN=FLOAT(I-1)/FLOAT(NLEVEL)*(AMX-AMN)+AMN                       GREYSC
      XMAX=XMIN+DELTA                                                   GREYSC
      LEV=LEVEL(I)                                                      GREYSC
      DO 175 J=1,LEV                                                    GREYSC
      IF(IFILEX.GT.0.AND.J.EQ.LEV) WRITE(IFILE,1020) ICHARS(I,J),XMIN,  GREYSC
     1  XMAX                                                            GREYSC
      IF(IFILEX.LT.0.AND.J.EQ.1) WRITE(IFILE,1020) ICHARS(I,J),XMIN,    GREYSC
     1 XMAX                                                             GREYSC
      IF(IFILEX.GT.0.AND.J.NE.LEV) WRITE(IFILE,1030) ICHARS(I,J)        GREYSC
      IF(IFILEX.LT.0.AND.J.NE.1) WRITE(IFILE,1030) ICHARS(I,J)          GREYSC
  175 CONTINUE                                                          GREYSC
  200 CONTINUE                                                          GREYSC
      RETURN                                                            GREYSC
 1000 FORMAT(1H0,20A6)                                                  GREYSC
 1001 FORMAT(1H0,20A4)                                                  GREYSC
 1002 FORMAT(1H0,12A10)                                                 GREYSC
 1003 FORMAT(1H0,24A5)                                                  GREYSC
 1010 FORMAT(1H0,32HGREY-SCALE CHARACTERS AND RANGES/1X)                GREYSC
 1020 FORMAT(5X,A1,5X,E15.6,5X,E15.6)                                   GREYSC
 1030 FORMAT(1H+,      4X,A1)                                           GREYSC
 1039 FORMAT(1H1)                                                       GREYSC
 1040 FORMAT(1H1/1X,20A6)                                               GREYSC
 1041 FORMAT(1H1/1X,20A4)                                               GREYSC
 1042 FORMAT(1H1/1X,12A10)                                              GREYSC
 1043 FORMAT(1H1/1X,24A5)                                               GREYSC
 1045 FORMAT(1H0,132A1)                                                 GREYSC
 1050 FORMAT(1X,132A1)                                                  GREYSC
 1060 FORMAT(1H+,     132A1)                                            GREYSC
```

```
      SUBROUTINE SIZE(ARRAY,MESHM,MESHN,X0,Y0,X2,Y2)

      THIS ROUTINE DETERMINES THE LOCATION OF THE CENTROID AND THE
      MEAN SQUARE WIDTH OF AN ARRAY

                             PARAMETERS

      ARRAY                  TWO DIMENSIONAL INPUT ARRAY
      MESH                   ARRAY HAS DIMENSION MESHXMESH
      X0,Y0                  X,Y COORDINATES OF CENTROID
      X2,Y2                  X AND Y RMS WIDTHS OF ARRAY

      LEVEL 2,ARRAY
      DIMENSION ARRAY(MESHM,MESHN)
      MIDM=MESHM/2+1
      MIDN=MESHN/2+1
      MID=MESH/2+1
      SUM1=0.
      SUM2=0.
      SUM3=0.
      SUM4=0.
      SUM5=0.
      DO 10 M=1,MESHM
      RM=M-MIDM
      RMSQ=RM*RM
      DO 10 N=1,MESHN
      RN=N-MIDN
      RNSQ=RN*RN
      ARMN=ARRAY(M,N)
      SUM1=SUM1+RM*ARMN
      SUM2=SUM2+RN*ARMN
      SUM3=SUM3+RMSQ*ARMN
      SUM4=SUM4+RNSQ*ARMN
      SUM5=SUM5+ARMN
   10 CONTINUE
      SNORM=1./SUM5
      X0=SNORM*SUM2
      Y0=SNORM*SUM1
      X2=SNORM*SUM4-X0*X0
      Y2=SNORM*SUM3-Y0*Y0
      X2=SQRT(X2)
      Y2=SQRT(Y2)
      RETURN
      END
```

REFERENCE MAP (R=1)

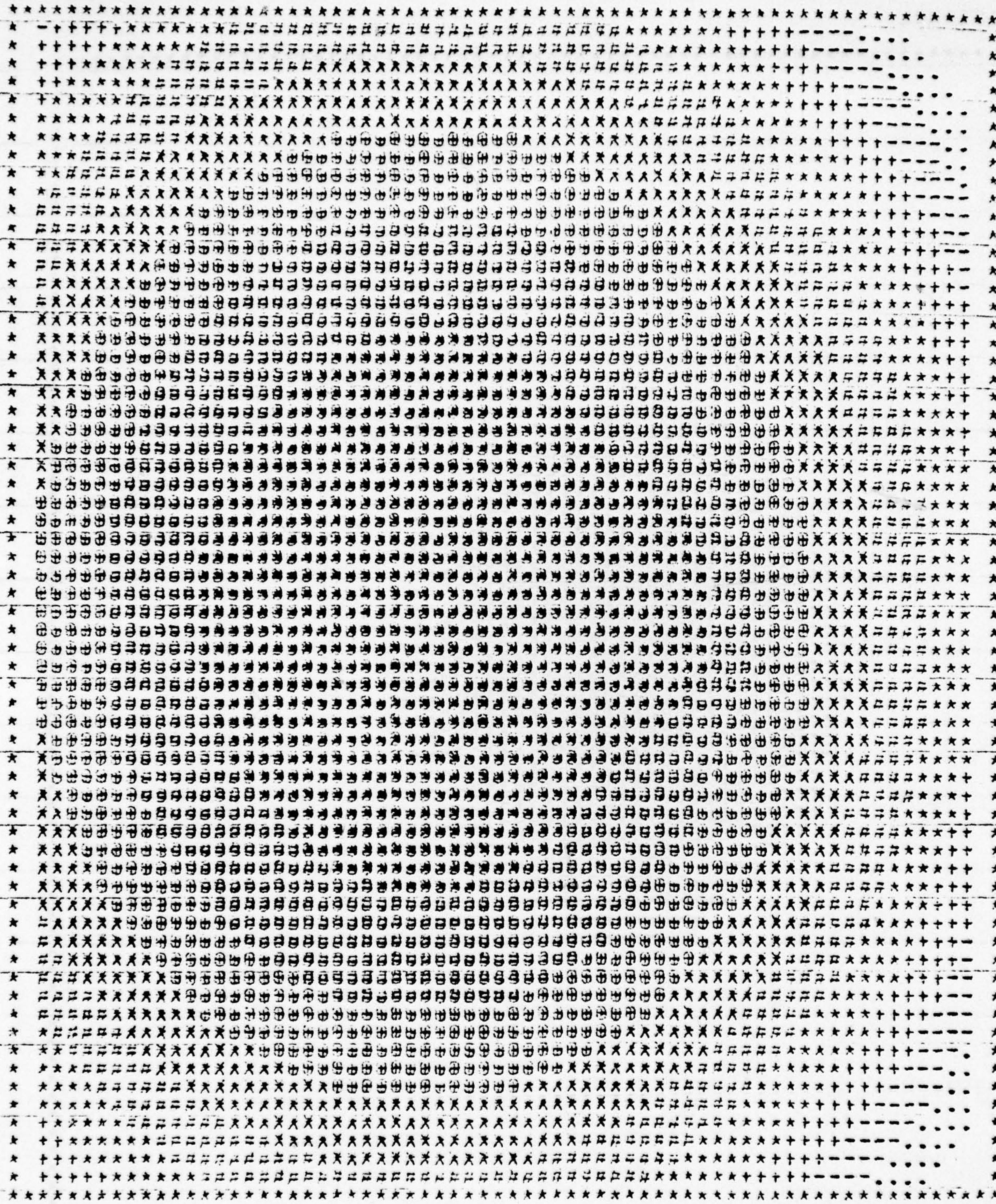
```
SYS.RM        127615         40  SL-SYSIO    11/08/77 COMPASS  3. 4-452
ERR.RM        127655        406  SL-SYSIO    11/08/77 COMPASS  3. 4-452
CHWP.SQ       130263          7  SL-SYSIO    11/08/77 COMPASS  3. 4-452
OSUB.RM       130272         71  SL-SYSIO    11/08/77 COMPASS  3. 4-452
OPEN.SQ       130363        257  SL-SYSIO    11/08/77 COMPASS  3. 4-452
OPEX.SQ       130642         14  SL-SYSIO    11/08/77 COMPASS  3. 4-452
/PUT.RT/      130656         11
RLEQ.RM       130667         50  SL-SYSIO    11/08/77 COMPASS  3. 4-452
CLSF.SQ       130737        136  SL-SYSIO    11/08/77 COMPASS  3. 4-452
/CLSV.FO/     131075          7
CLSV.SQ       131104        137  SL-SYSIO    11/08/77 COMPASS  3. 4-452
/REW.FO/      131243          7
REW.SQ        131252         42  SL-SYSIO    11/08/77 COMPASS  3. 4-452
/GET.FO/      131314          7
/RPAR.XX/     131323          1
/GET.RT/      131324         11
GET.SQ        131335       1070  SL-SYSIO    11/08/77 COMPASS  3. 4-452
Z.SQ          132425        125  SL-SYSIO    11/08/77 COMPASS  3. 4-452
FSU.SQ        132552        107  SL-SYSIO    11/08/77 COMPASS  3. 4-452
/LCM2/      40000000     141000

        .213 CP SECONDS                 150200B CM STORAGE USED

0. -6. 0. 6.
.00081 .00081
50. 25.
```

```
LAMBDA   = .8E+00,
RO       = .5E+02,
FR       = .5E+02,
NO       = .15E+01,
PCDRP    = .81E-03,
OUTRAD   = .1E+04,
DX       = .5E+01,
NSTEPS   = 40,
NDZINC   = 5,
IOUT     = 6,
IGREY    = 6,
PGREY    = T,
PWAIST   = T,
PLTWST   = F,
PLTMAX   = F,
PLTFLD   = F,
PLTFLE   = F,
MESH     = 128,
$END
ZMIN = 19513.3742 MICRONS
DZINC =   3902.6748 MICRONS
RN2NO =    .648E-08 MICRONS**(-2)
ALPHA =       .42179
```

REFNDX

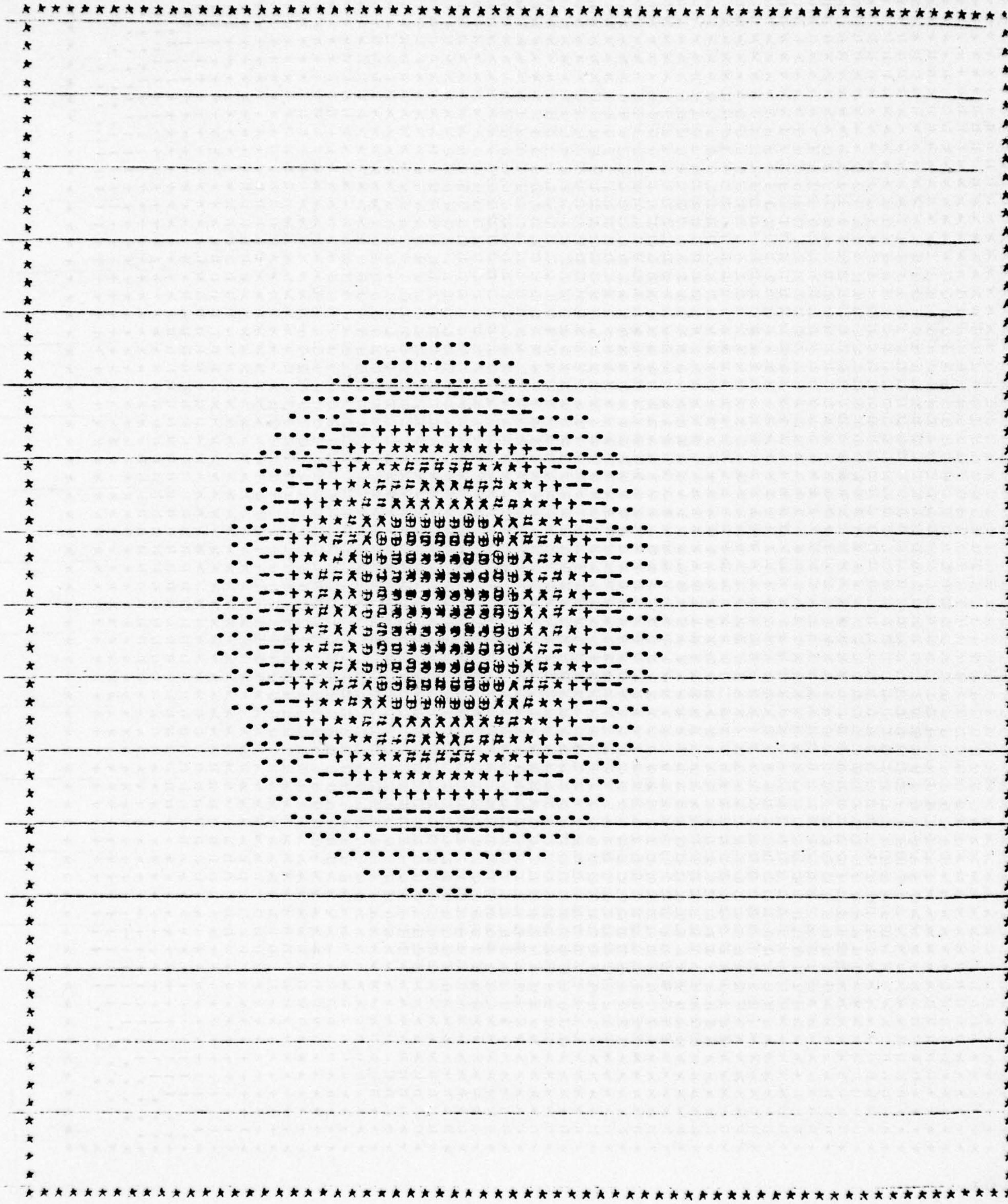


REFNDX

GREY-SCALE CHARACTERS AND RANGES

	-.872164E-03	-.784948E-03
.	-.784948E-03	-.697731E-03
-	-.697731E-03	-.610515E-03
+	-.610515E-03	-.523298E-03
*	-.523298E-03	-.436082E-03
=	-.436082E-03	-.348866E-03
X	-.348866E-03	-.261649E-03
⊕	-.261649E-03	-.174433E-03
θ	-.174433E-03	-.872164E-04
●	[illegible]	[illegible]

IRRADIANCE

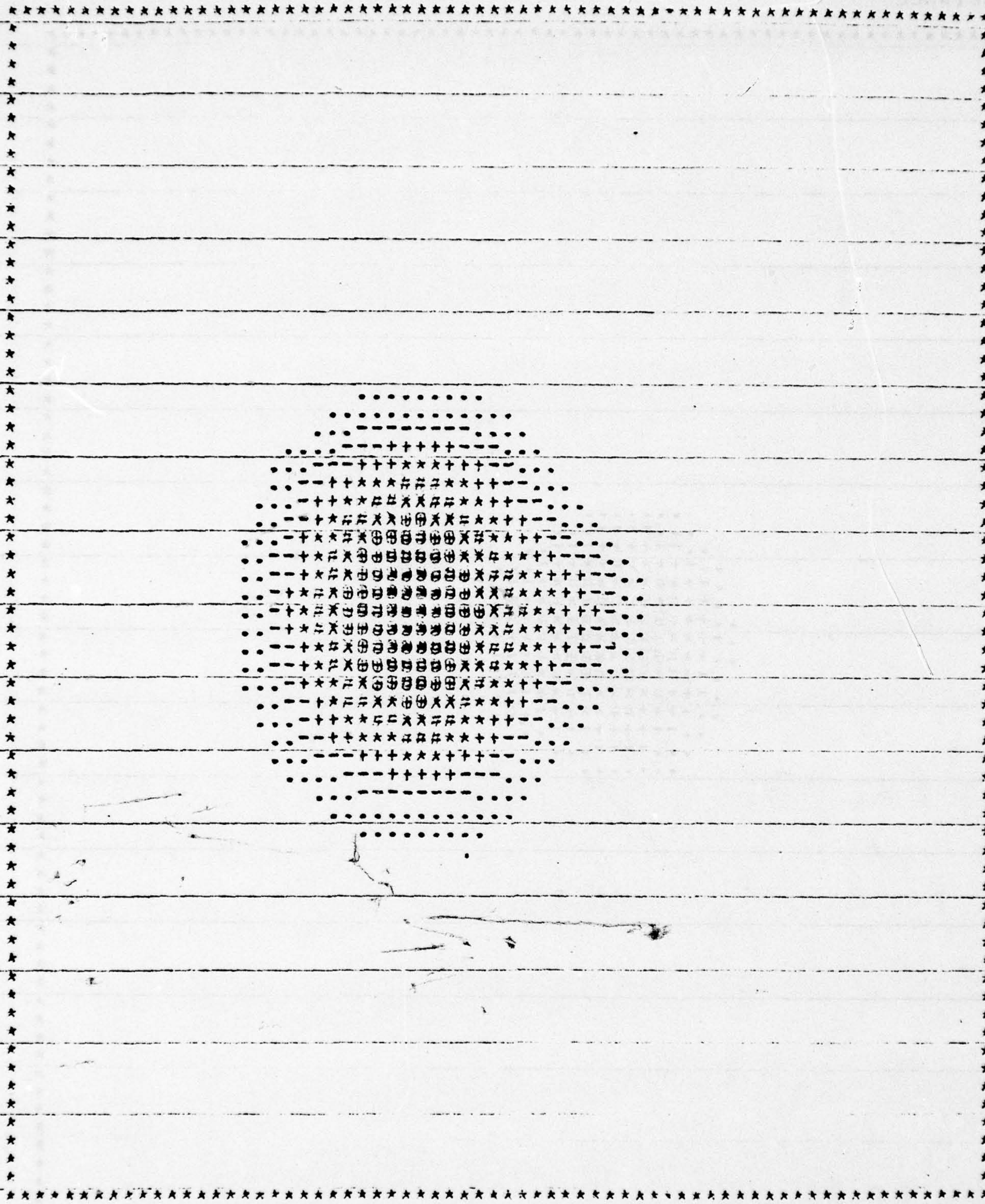


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.404886E-10	.100000E+00
.	.100000E+00	.200000E+00
-	.200000E+00	.300000E+00
+	.300000E+00	.400000E+00
*	.400000E+00	.500000E+00
=	.500000E+00	.600000E+00
X	.600000E+00	.700000E+00
@	.700000E+00	.800000E+00
#	.800000E+00	.900000E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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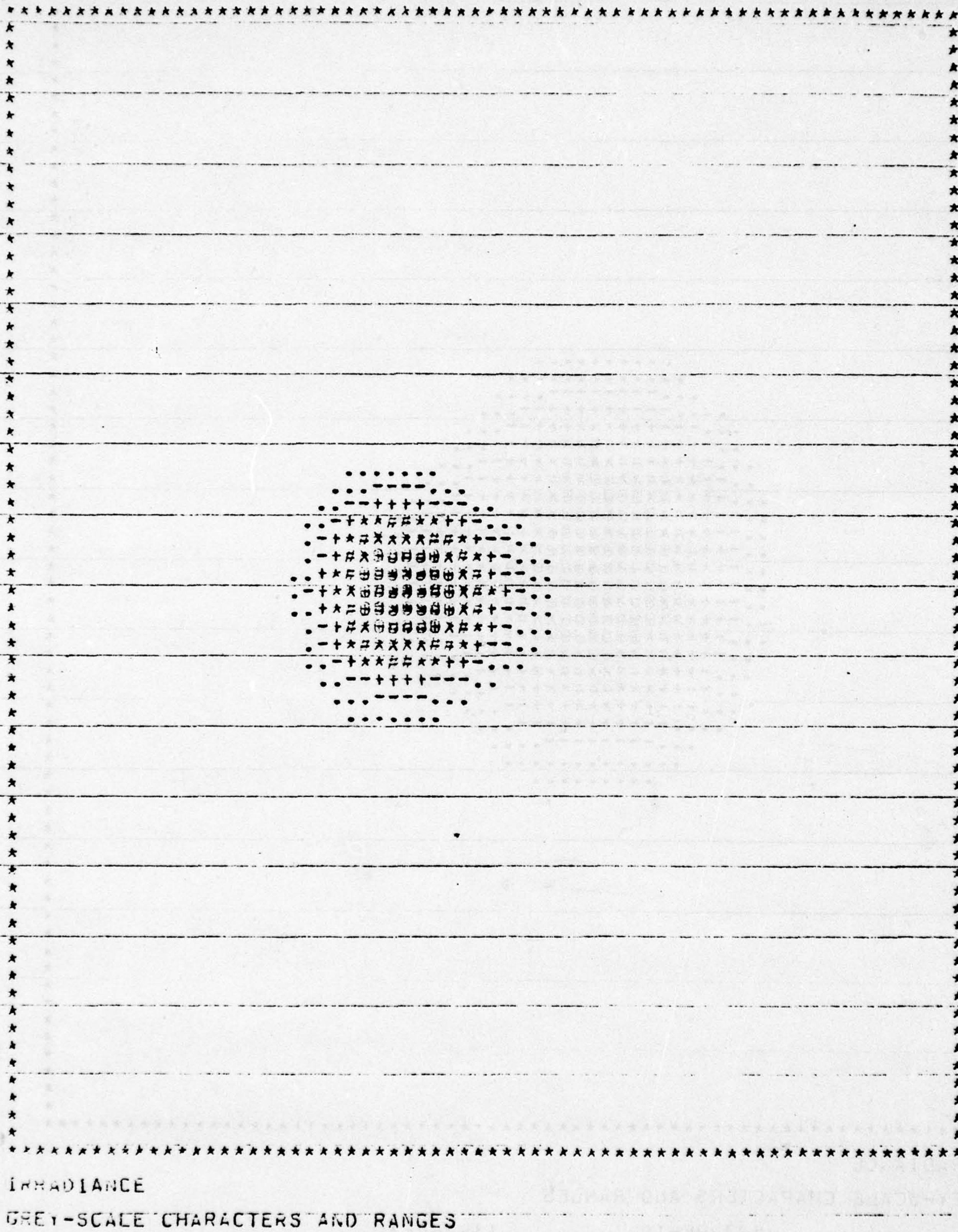
.	.139260E+00	.278520E+00
-	.278520E+00	.417779E+00
+	.417779E+00	.557039E+00
*	.557039E+00	.696299E+00
=	.696299E+00	.835559E+00
X	.835559E+00	.974819E+00
@	.974819E+00	.111408E+01
[illegible]	[illegible]	[illegible]

IRRADIANCE

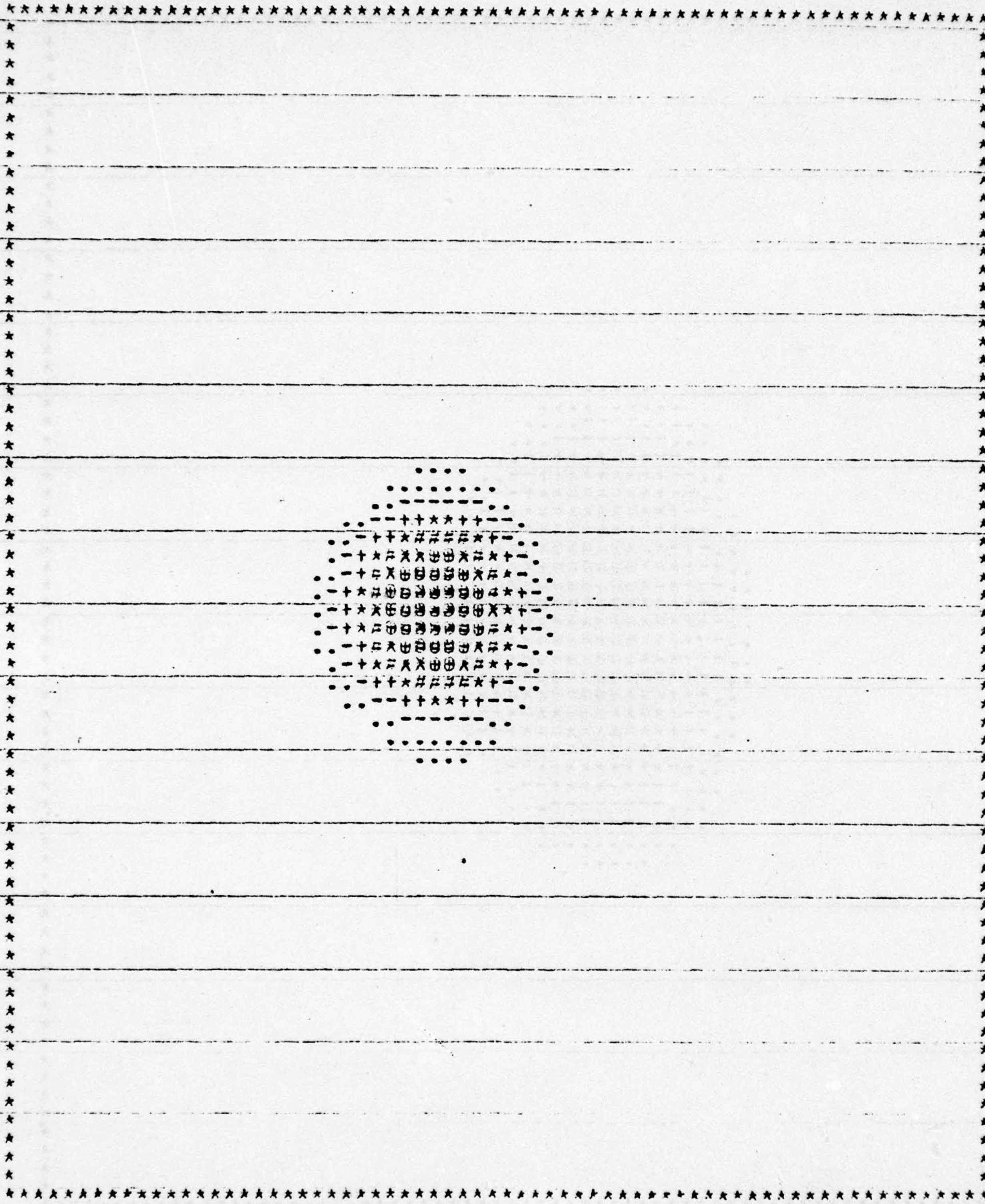


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.133750E-07	.334463E+00
.	.334463E+00	.668927E+00
-	.668927E+00	.100339E+01
+	.100339E+01	.133785E+01
*	.133785E+01	.167232E+01
=	.167232E+01	.200678E+01
X	.200678E+01	.234124E+01
⊕	.234124E+01	.267571E+01
@	.267571E+01	.301017E+01

IRRADIANCE

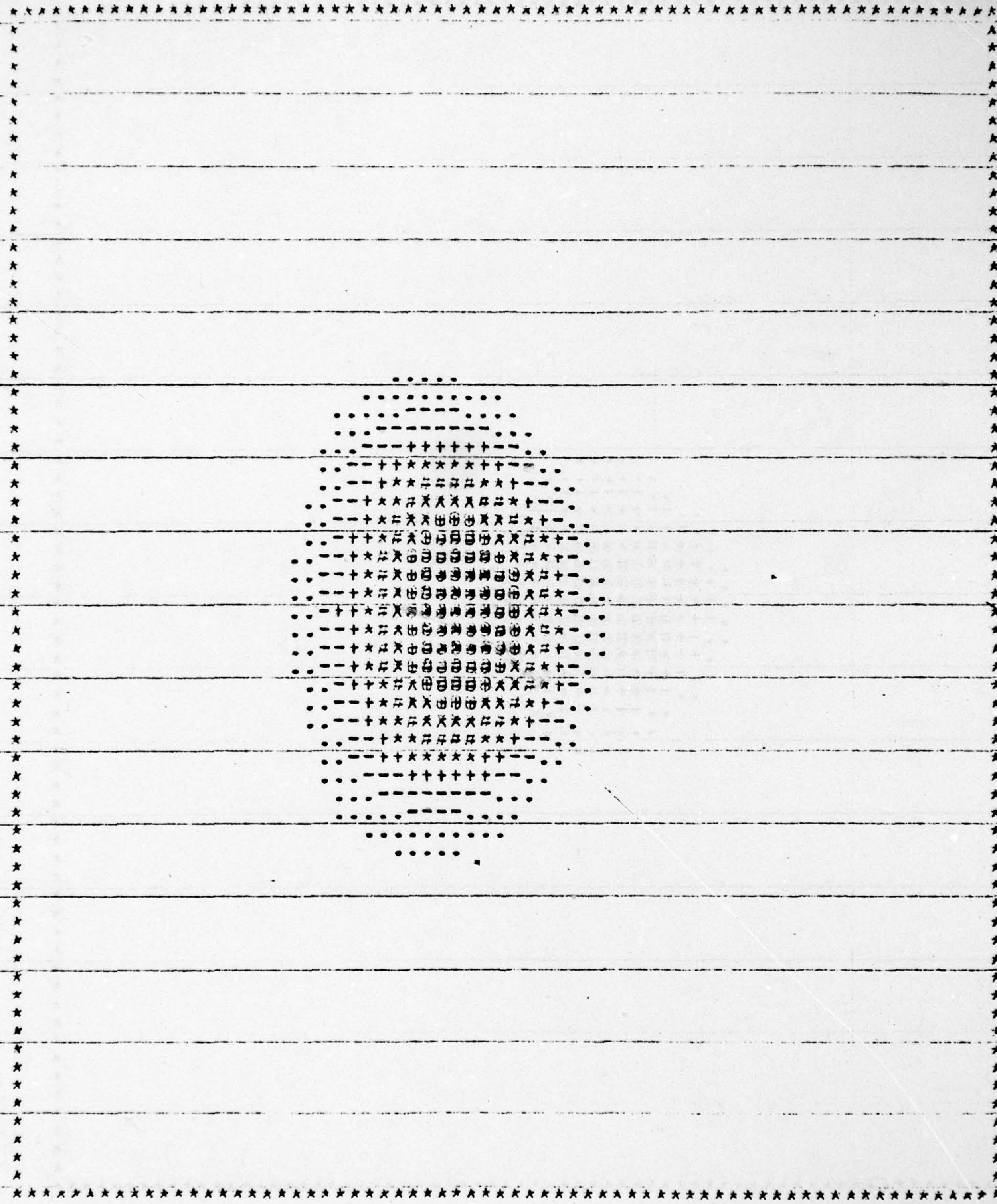


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.597046E-08	.335547E+00
.	.335547E+00	.671094E+00
-	.671094E+00	.100664E+01
+	.100664E+01	.134219E+01
*	.134219E+01	.167773E+01
#	.167773E+01	.201328E+01
X	.201328E+01	.234883E+01
@	.234883E+01	.268437E+01

IRRADIANCE

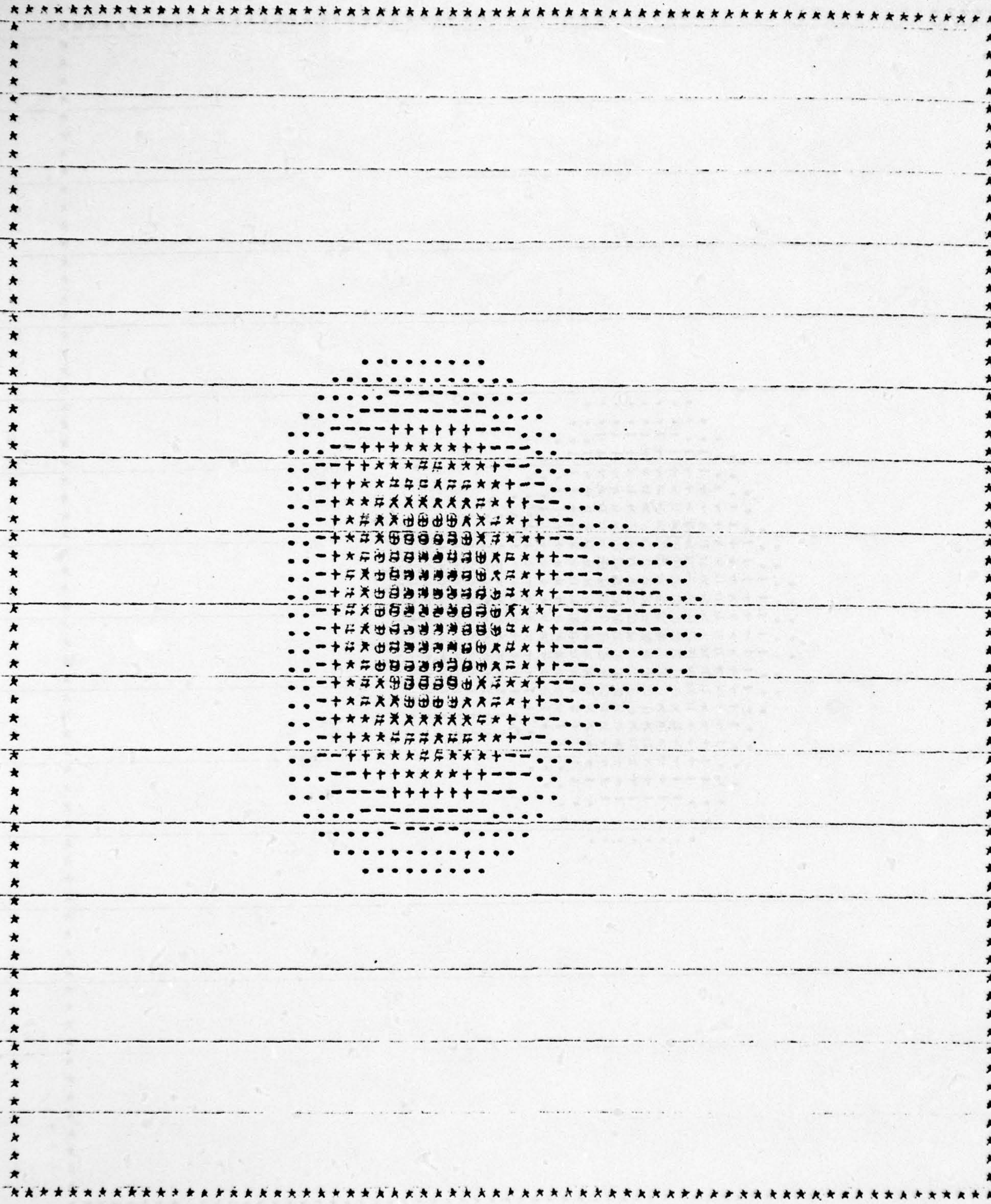


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.203232E-06	.155352E+00
.	.155352E+00	.310703E+00
-	.310703E+00	.466054E+00
+	.466054E+00	.621406E+00
*	.621406E+00	.776757E+00
≠	.776757E+00	.932109E+00
X	.932109E+00	.108746E+01
⊕	.108746E+01	.124281E+01
Θ	.124281E+01	.139816E+01

IRRADIANCE

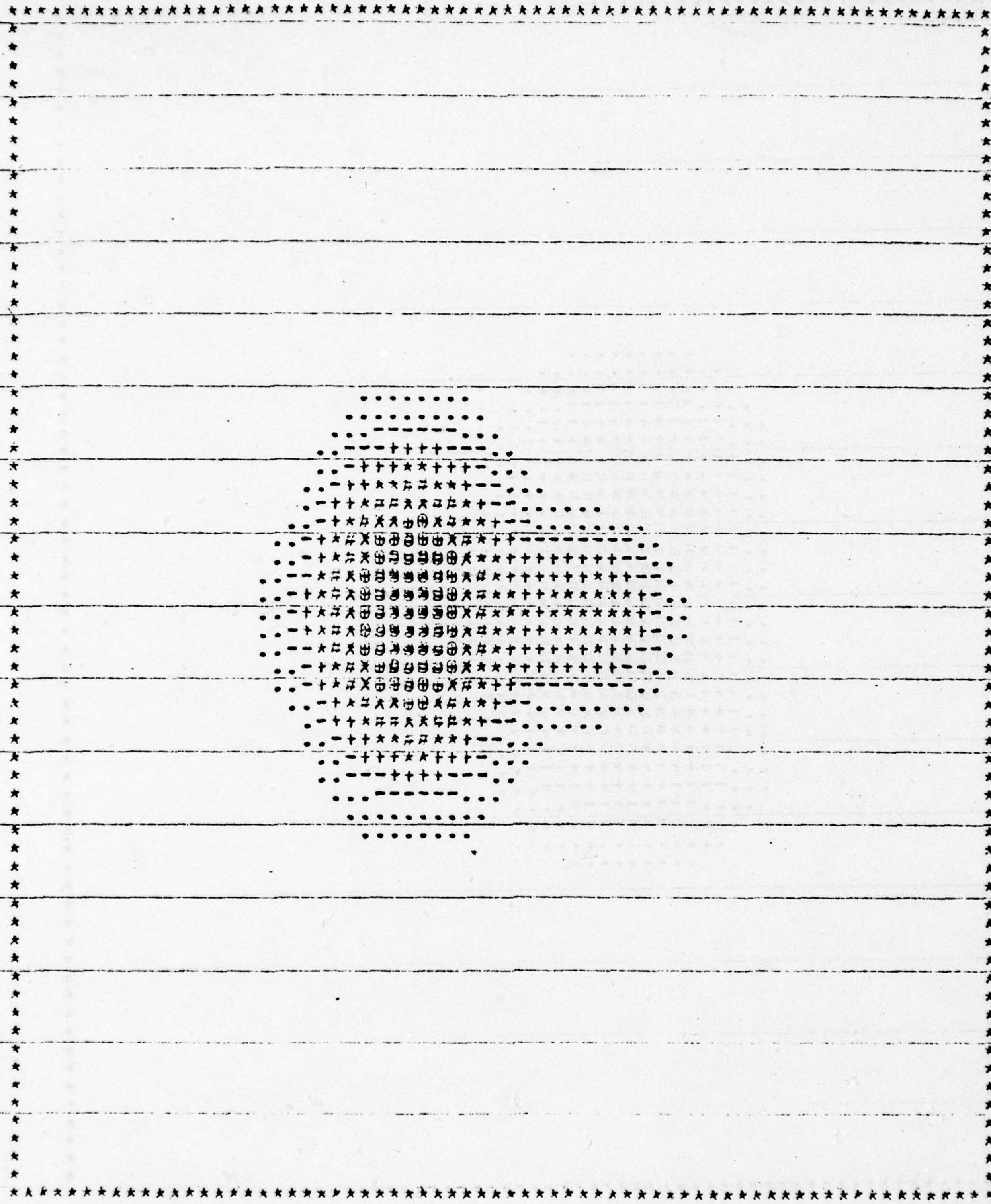


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.128679E-06	.125381E+00
.	.125381E+00	.250761E+00
-	.250761E+00	.376142E+00
+	.376142E+00	.501523E+00
*	.501523E+00	.626903E+00
#	.626903E+00	.752284E+00
X	.752284E+00	.877665E+00
@	.877665E+00	.100305E+01

IRRADIANCE

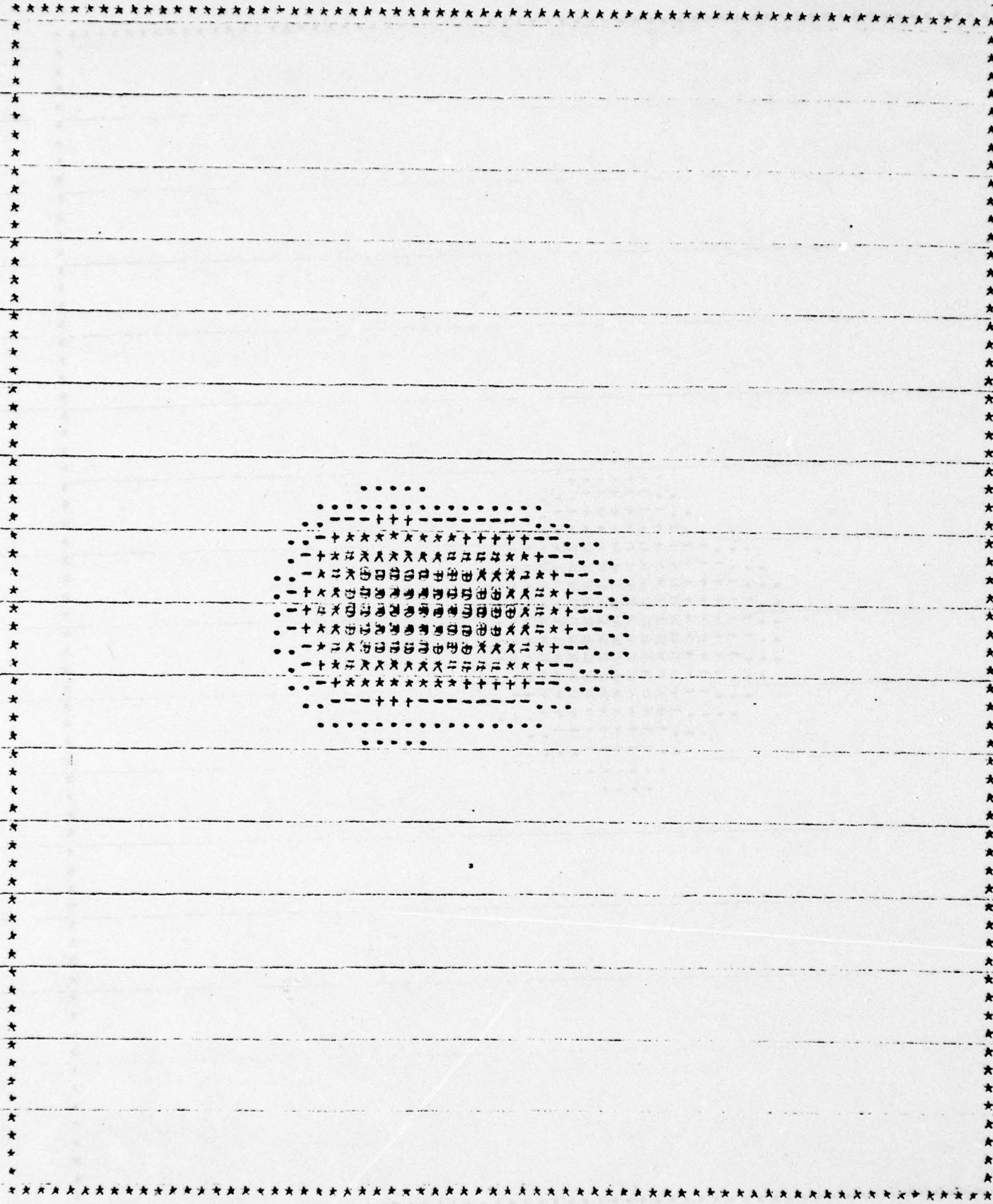


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.968125E-07	.150883E+00
.	.150883E+00	.301767E+00
-	.301767E+00	.452650E+00
+	.452650E+00	.603533E+00
*	.603533E+00	.754417E+00
=	.754417E+00	.905300E+00
X	.905300E+00	.105618E+01
@	.105618E+01	.120707E+01
[illegible]	.120707E+01	[illegible]

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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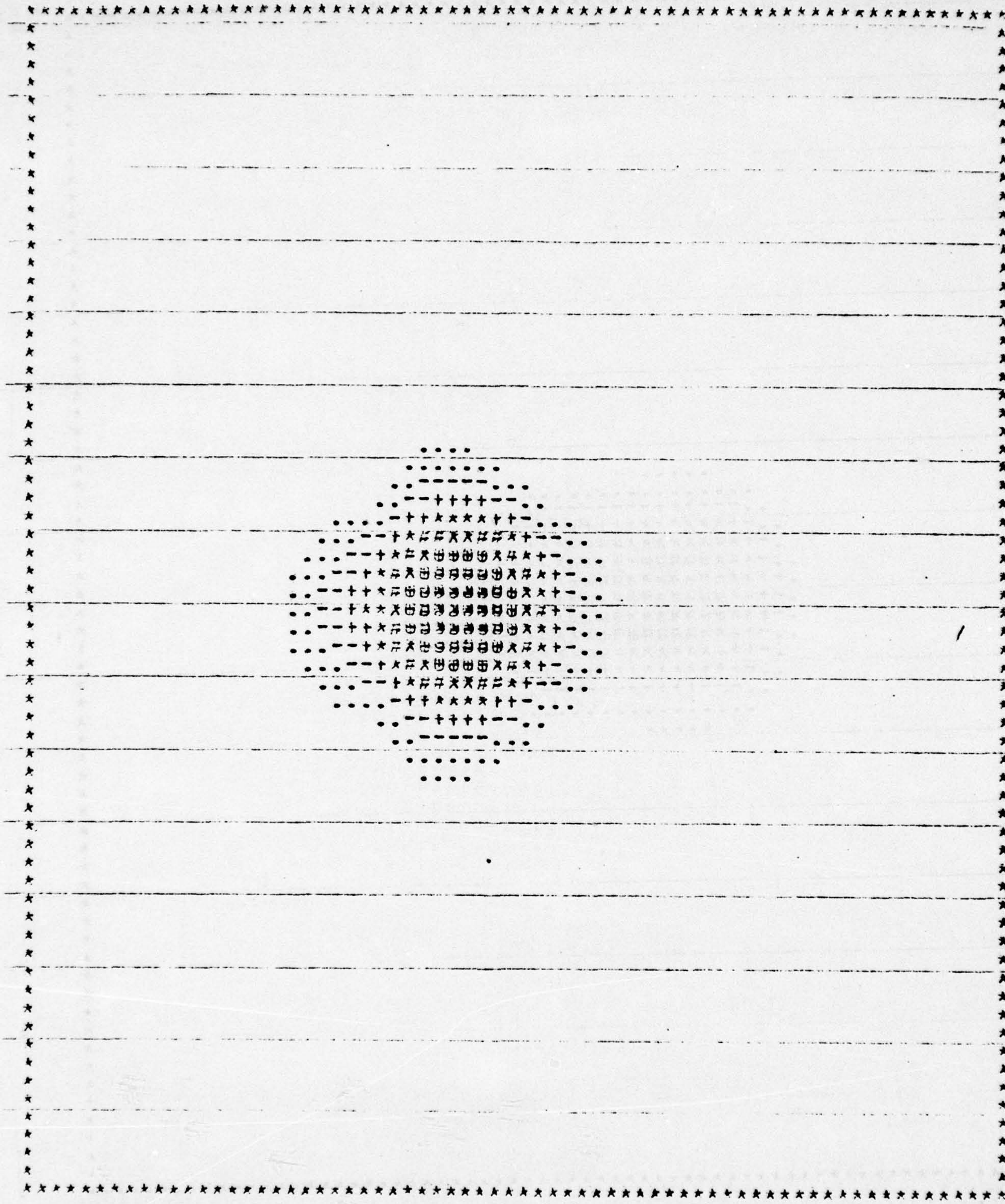
.	.238982E+00	.477964E+00
-	.477964E+00	.716946E+00
+	.716946E+00	.955928E+00
*	.955928E+00	.119491E+01
#	.119491E+01	.143389E+01
X	.143389E+01	.167287E+01
@	.167287E+01	.191186E+01
[illegible]	[illegible]	[illegible]

IRRADIANCE

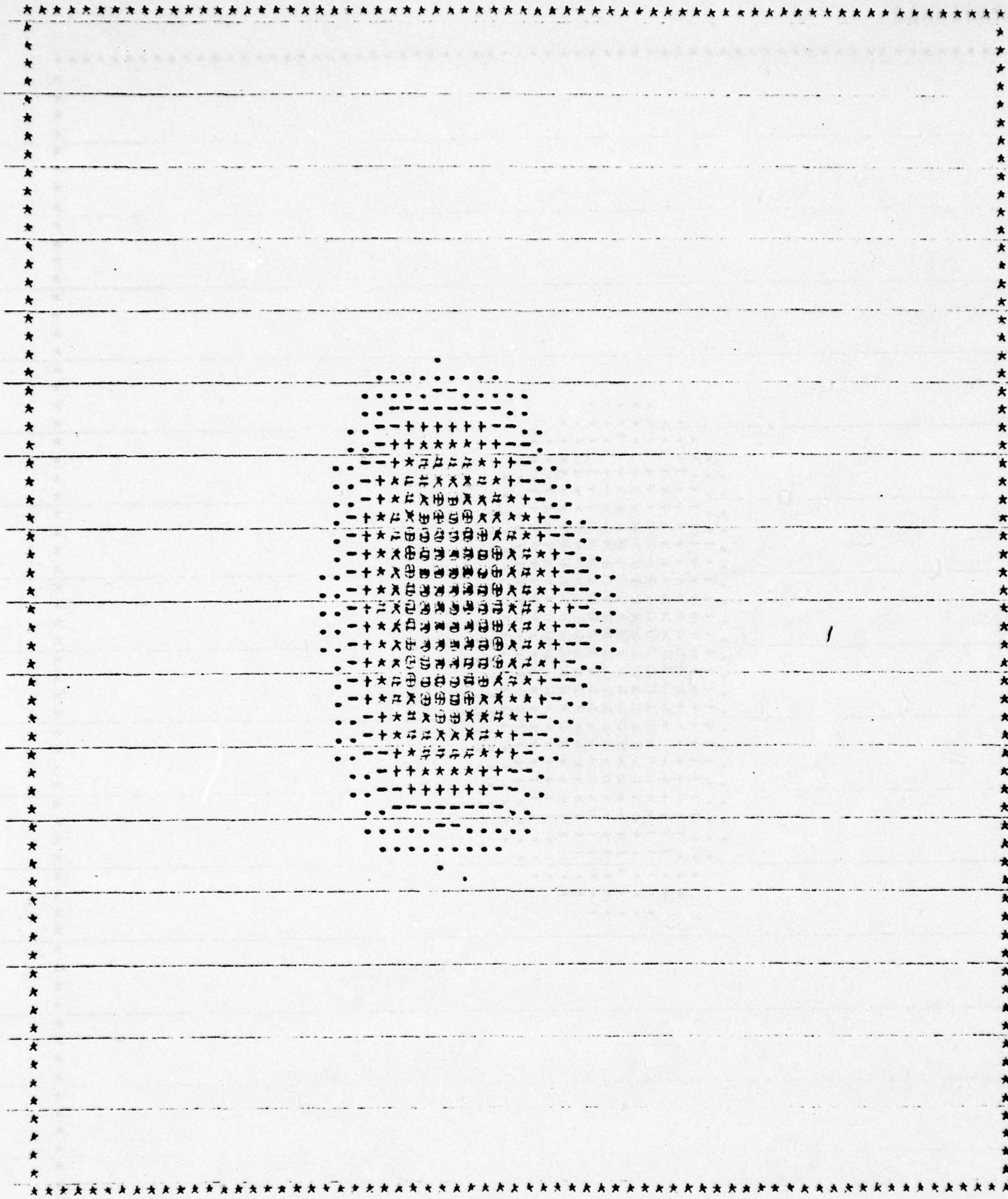


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.791265E-08	.250854E+00
.	.250854E+00	.501708E+00
-	.501708E+00	.752562E+00
+	.752562E+00	.100342E+01
*	.100342E+01	.125427E+01
=	.125427E+01	.150512E+01
X	.150512E+01	.175598E+01
@	.175598E+01	.200683E+01
#	.200683E+01	.225768E+01

IRRADIANCE

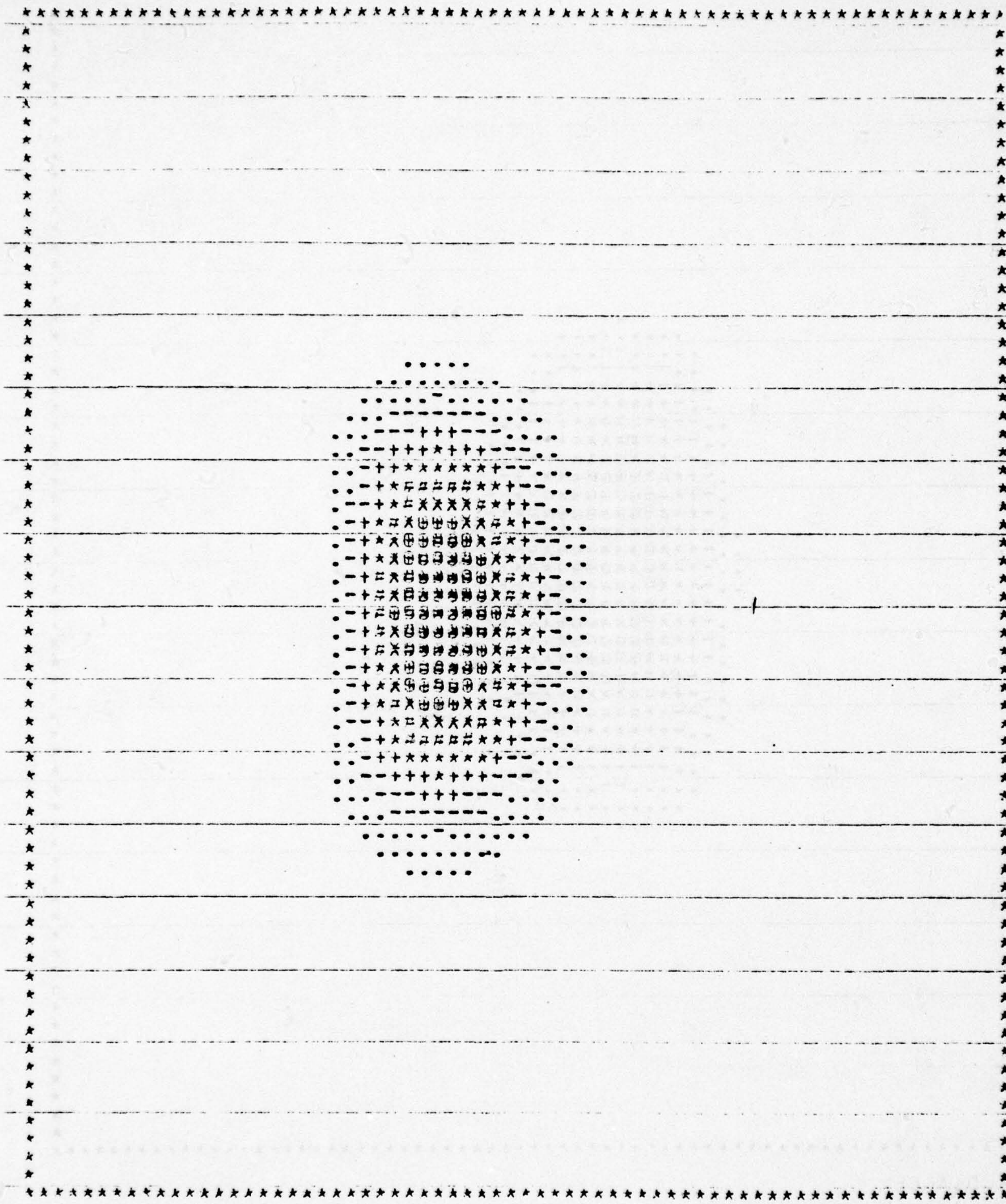


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.274744E-07	.158942E+00
.	.158942E+00	.317884E+00
-	.317884E+00	.476827E+00
+	.476827E+00	.635769E+00
*	.635769E+00	.794711E+00
=	.794711E+00	.953653E+00
X	.953653E+00	.111260E+01
⊕	.111260E+01	.127154E+01
⊞	.127154E+01	.143048E+01

IRRADIANCE

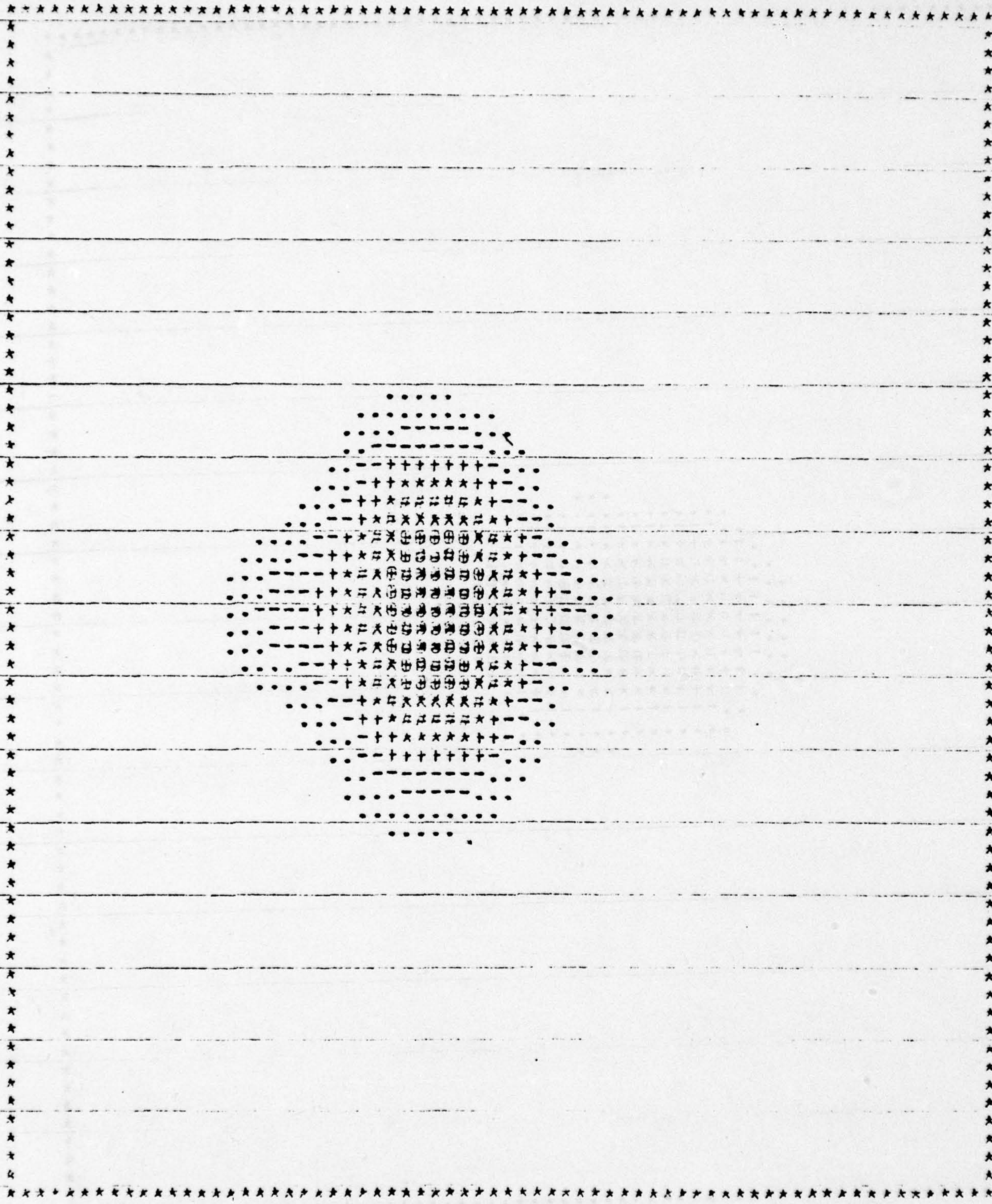


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.990012E-07	.163531E+00
.	.163531E+00	.327062E+00
-	.327062E+00	.490593E+00
+	.490593E+00	.654124E+00
*	.654124E+00	.817655E+00
≠	.817655E+00	.981186E+00
X	.981186E+00	.114472E+01
@	.114472E+01	.130825E+01
[illegible]	[illegible]	[illegible]

IRRADIANCE

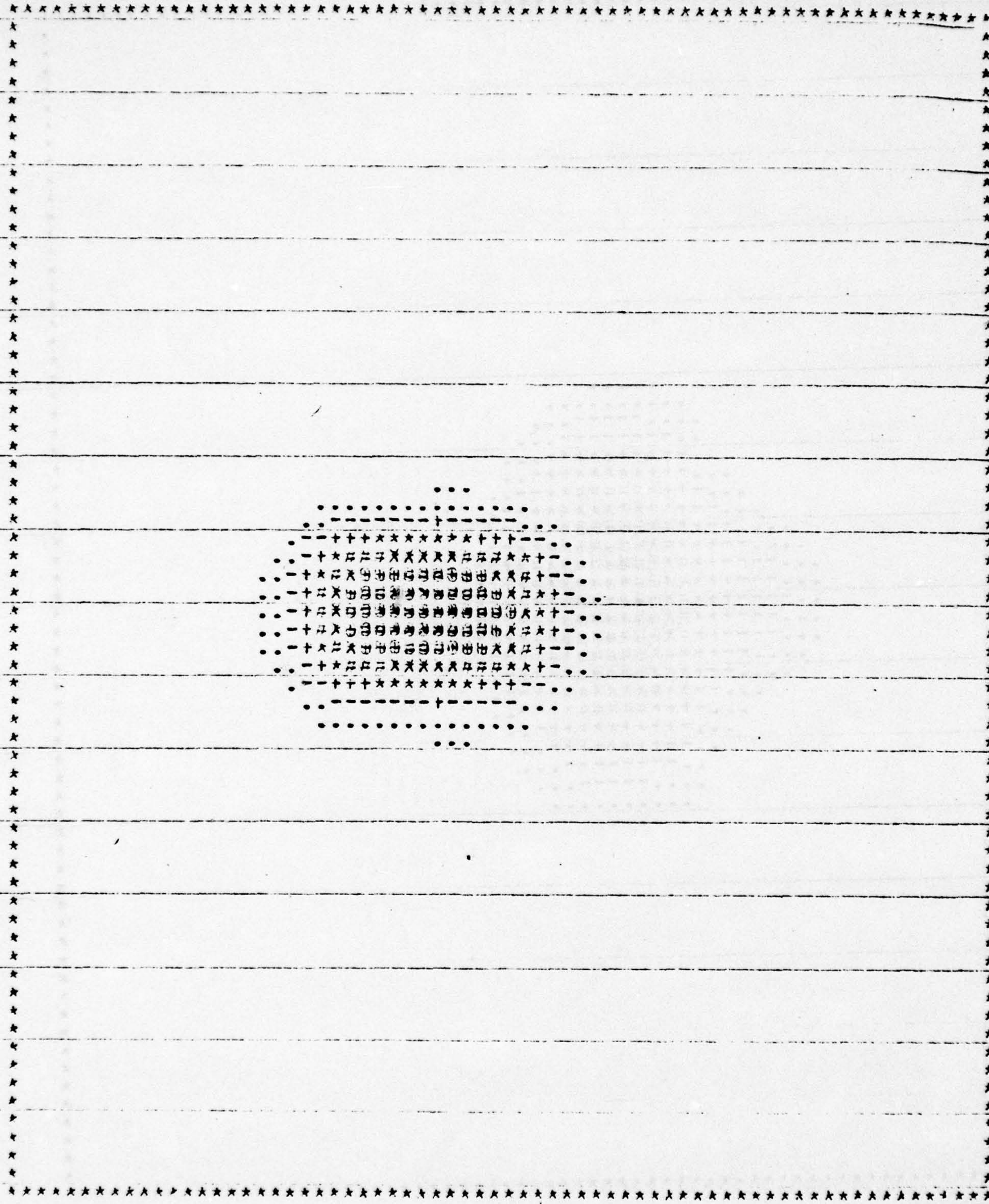


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.673243E-07	.174282E+00
.	.174282E+00	.348565E+00
-	.348565E+00	.522847E+00
+	.522847E+00	.697129E+00
*	.697129E+00	.871412E+00
#	.871412E+00	.104569E+01
X	.104569E+01	.121994E+01

IRRADIANCE

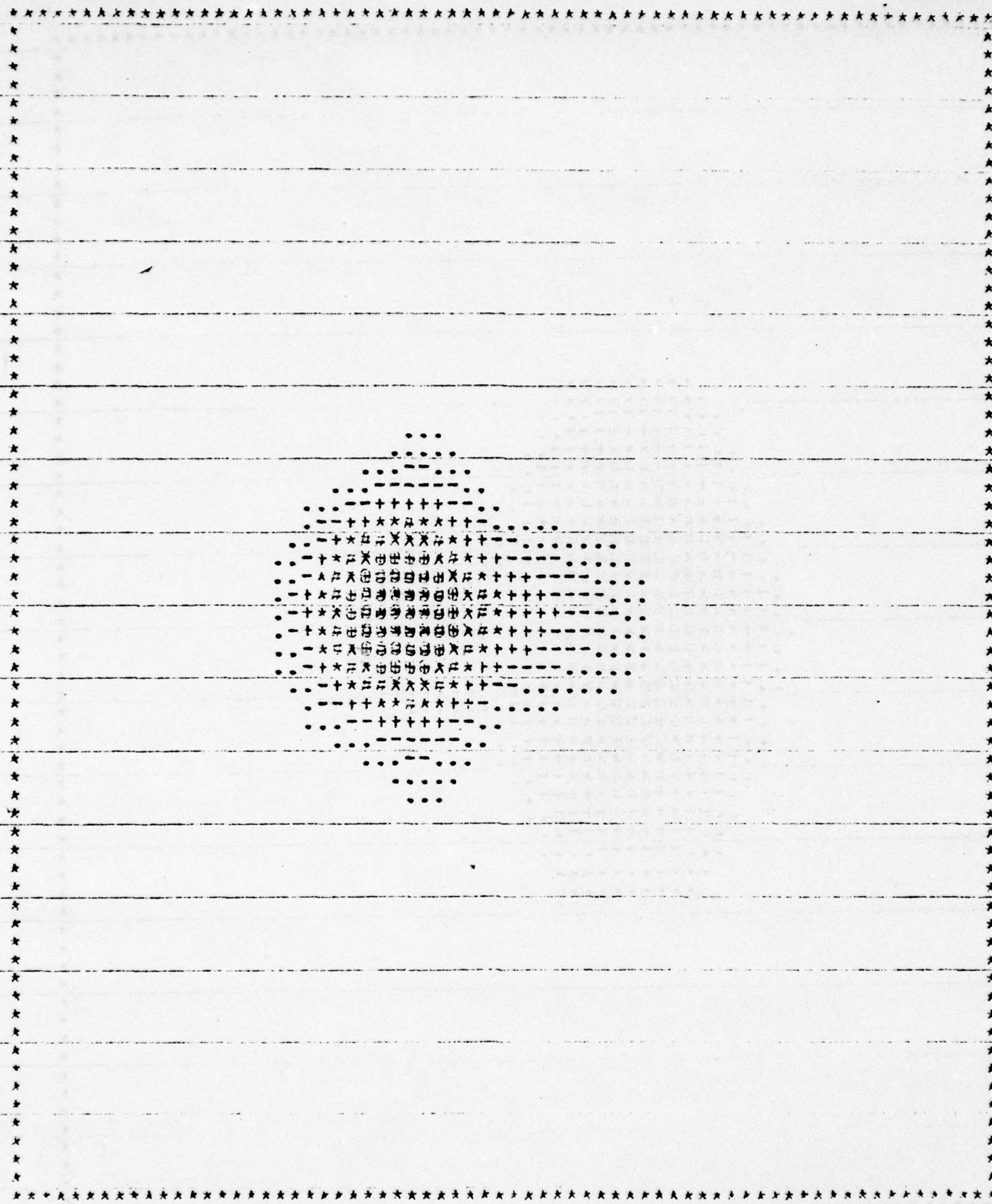


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.130120E-07	.247546E+00
.	.247546E+00	.495092E+00
-	.495092E+00	.742639E+00
+	.742639E+00	.990185E+00
*	.990185E+00	.123773E+01
#	.123773E+01	.148528E+01
X	.148528E+01	.173282E+01
@	.173282E+01	.198037E+01
[illegible]	[illegible]	[illegible]

IRRADIANCE

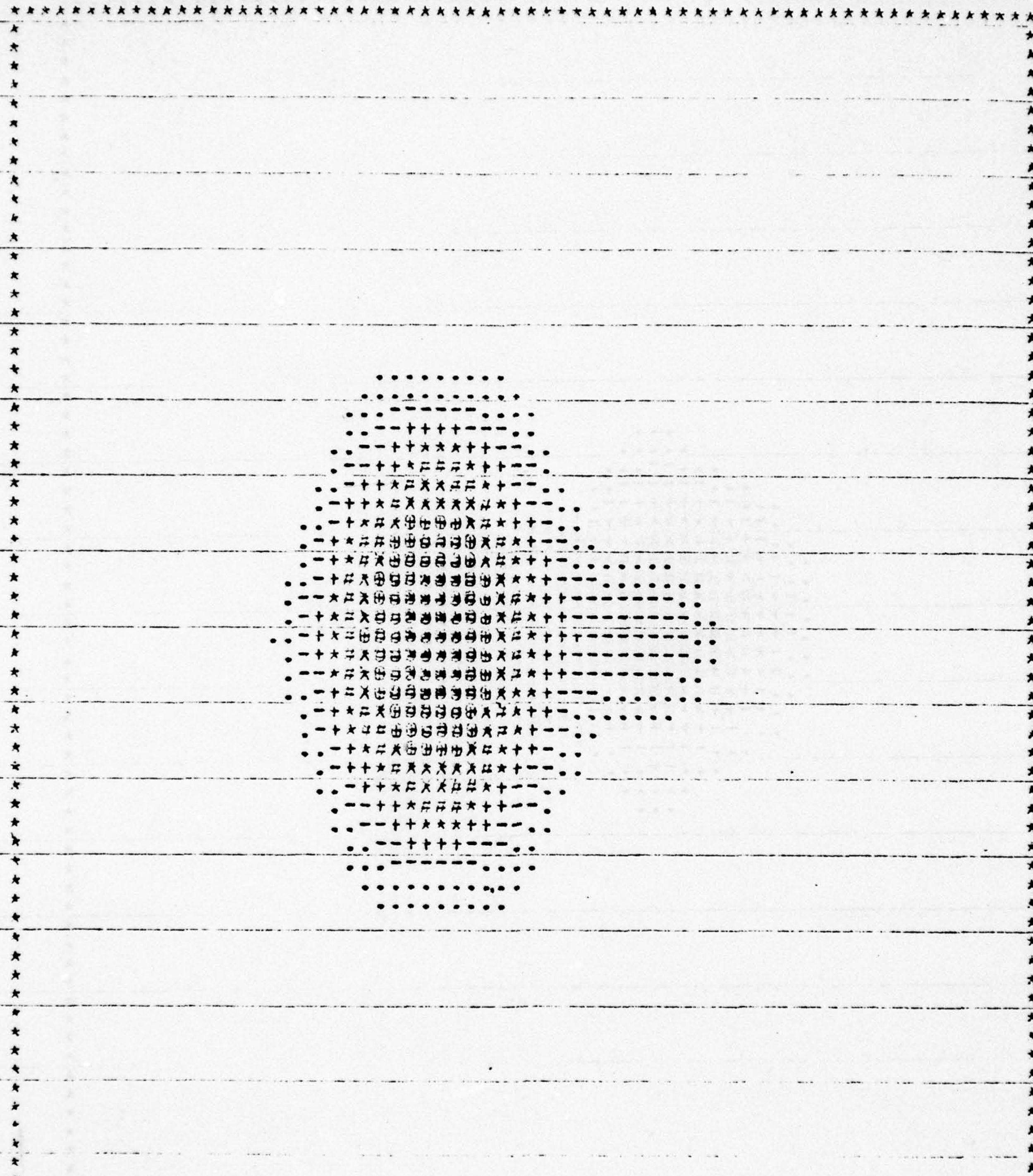


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.585799E-07	.226294E+00
.	.226294E+00	.452587E+00
-	.452587E+00	.678881E+00
+	.678881E+00	.905174E+00
*	.905174E+00	.113147E+01
#	.113147E+01	.135776E+01
X	.135776E+01	.158405E+01
$	.158405E+01	.181035E+01

IRRADIANCE

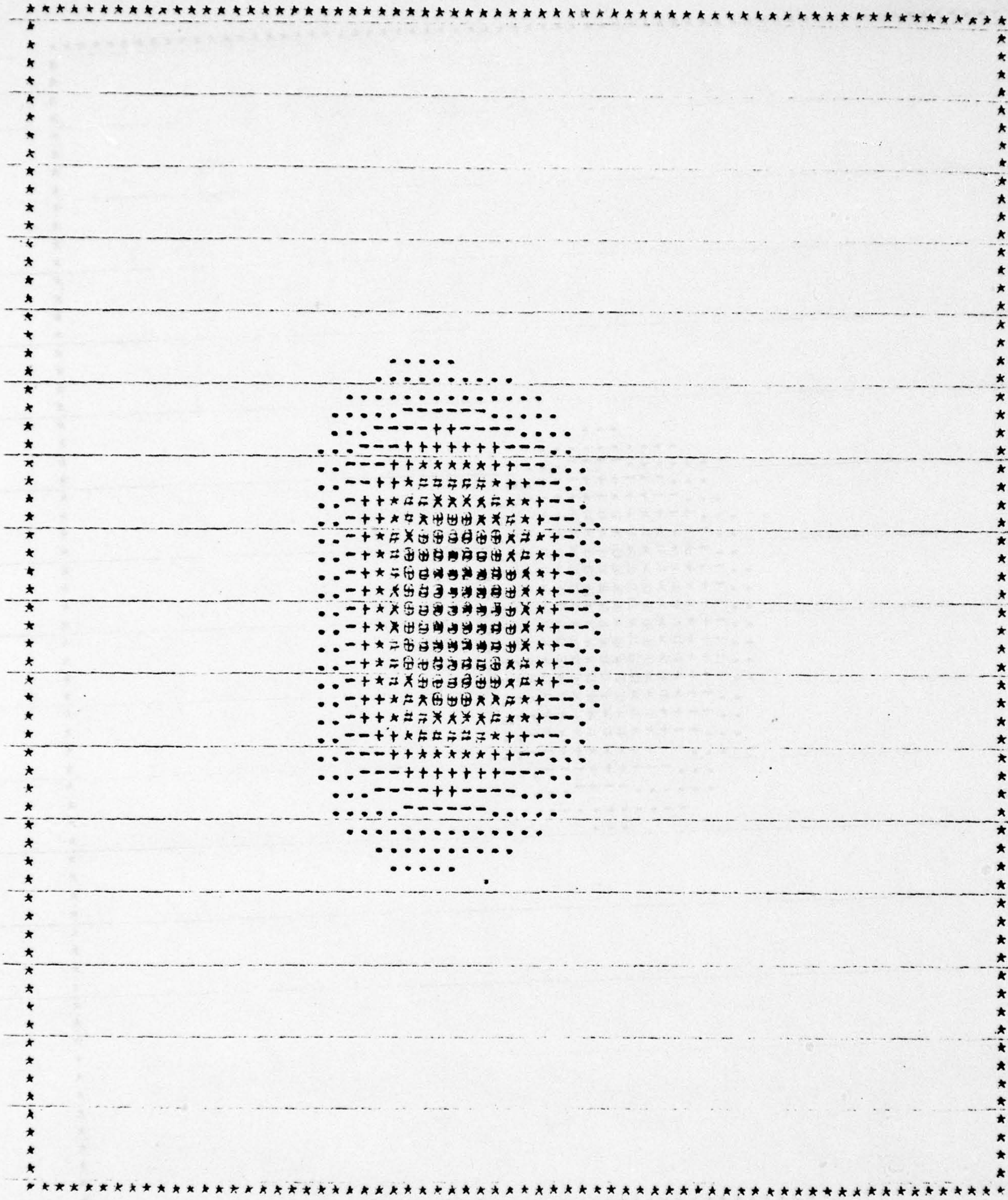


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.663345E-07	.131651E+00
.	.131651E+00	.263303E+00
-	.263303E+00	.394954E+00
+	.394954E+00	.526605E+00
*	.526605E+00	.658257E+00
#	.658257E+00	.789908E+00
X	.789908E+00	.921559E+00
@	.921559E+00	.105321E+01
[illegible]	.105321E+01	.118486E+01

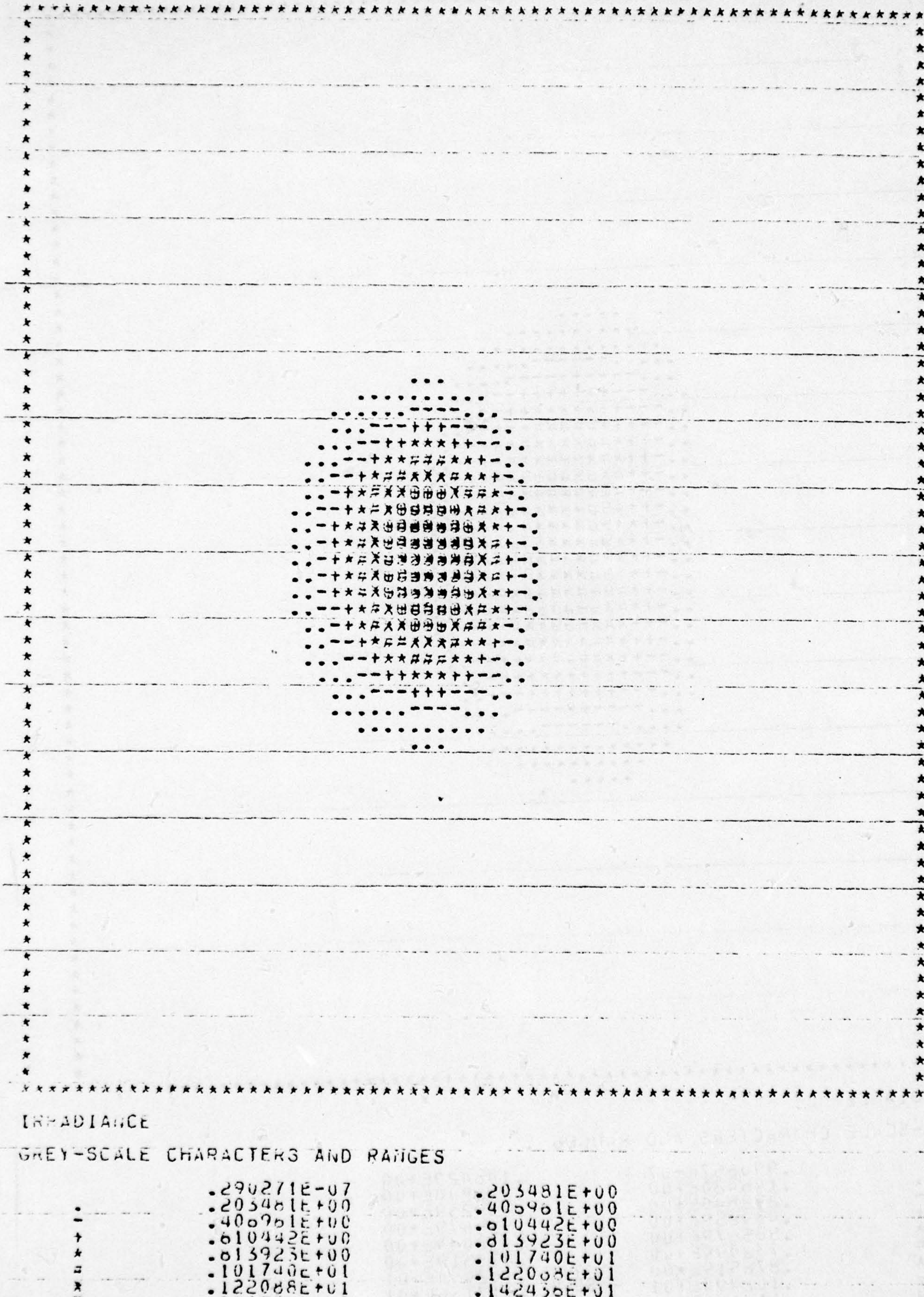
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.990657E-07	.146420E+00
.	.146420E+00	.292840E+00
-	.292840E+00	.439259E+00
+	.439259E+00	.585679E+00
*	.585679E+00	.732099E+00
=	.732099E+00	.878519E+00
X	.878519E+00	.102494E+01
@	.102494E+01	.117136E+01
#	.117136E+01	.131778E+01
M	.131778E+01	[illegible]

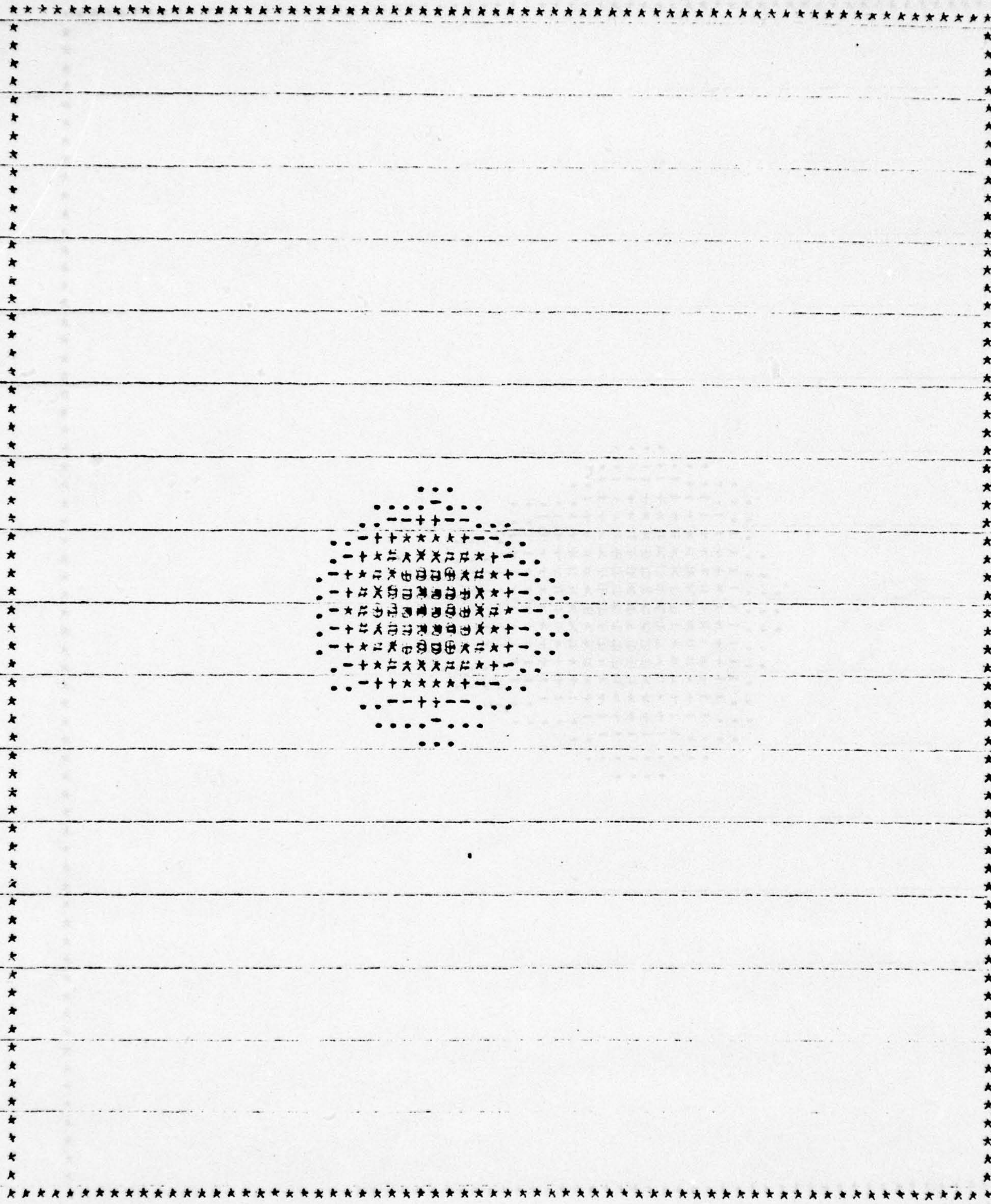


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.290271E-07	.203481E+00
.	.203481E+00	.406961E+00
-	.406961E+00	.610442E+00
+	.610442E+00	.813923E+00
*	.813923E+00	.101740E+01
=	.101740E+01	.122088E+01
X	.122088E+01	.142436E+01
@	.142436E+01	.162785E+01
#	.162785E+01	.183133E+01
#	.183133E+01	[illegible]

IRRADIANCE

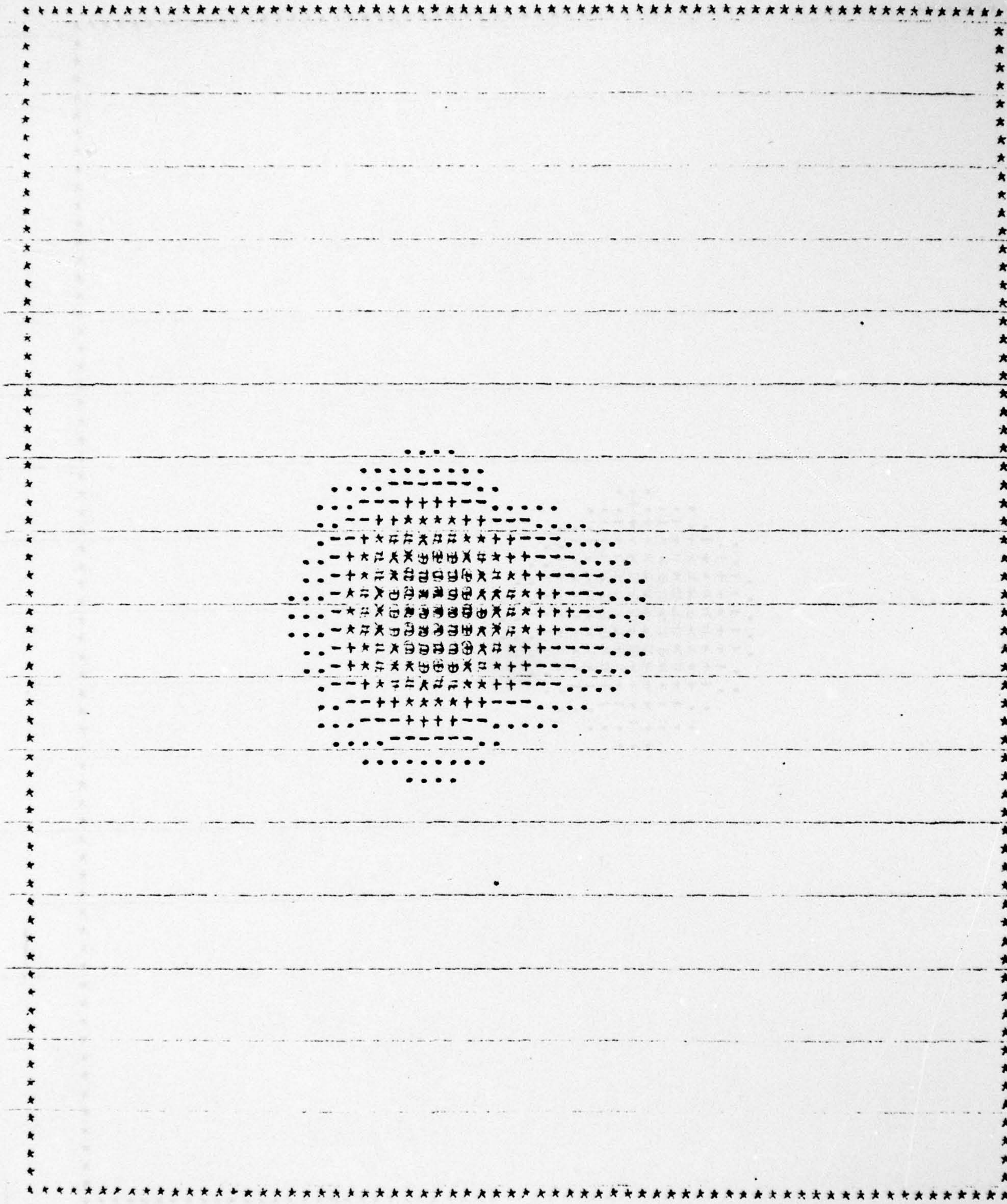


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.285066E-06	.370406E+00
.	.370406E+00	.740813E+00
-	.740813E+00	.111122E+01
+	.111122E+01	.148163E+01
*	.148163E+01	.185203E+01
=	.185203E+01	.222244E+01
X	.222244E+01	.259284E+01
@	.259284E+01	[illegible]

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.460035E-09	.238776E+00
.	.238776E+00	.477552E+00
-	.477552E+00	.716328E+00
+	.716328E+00	.955103E+00
*	.955103E+00	.119388E+01
=	.119388E+01	.143266E+01
X	.143266E+01	.167143E+01
#	.167143E+01	.191021E+01
@	.191021E+01	.214898E+01
■	.214898E+01	.238776E+01

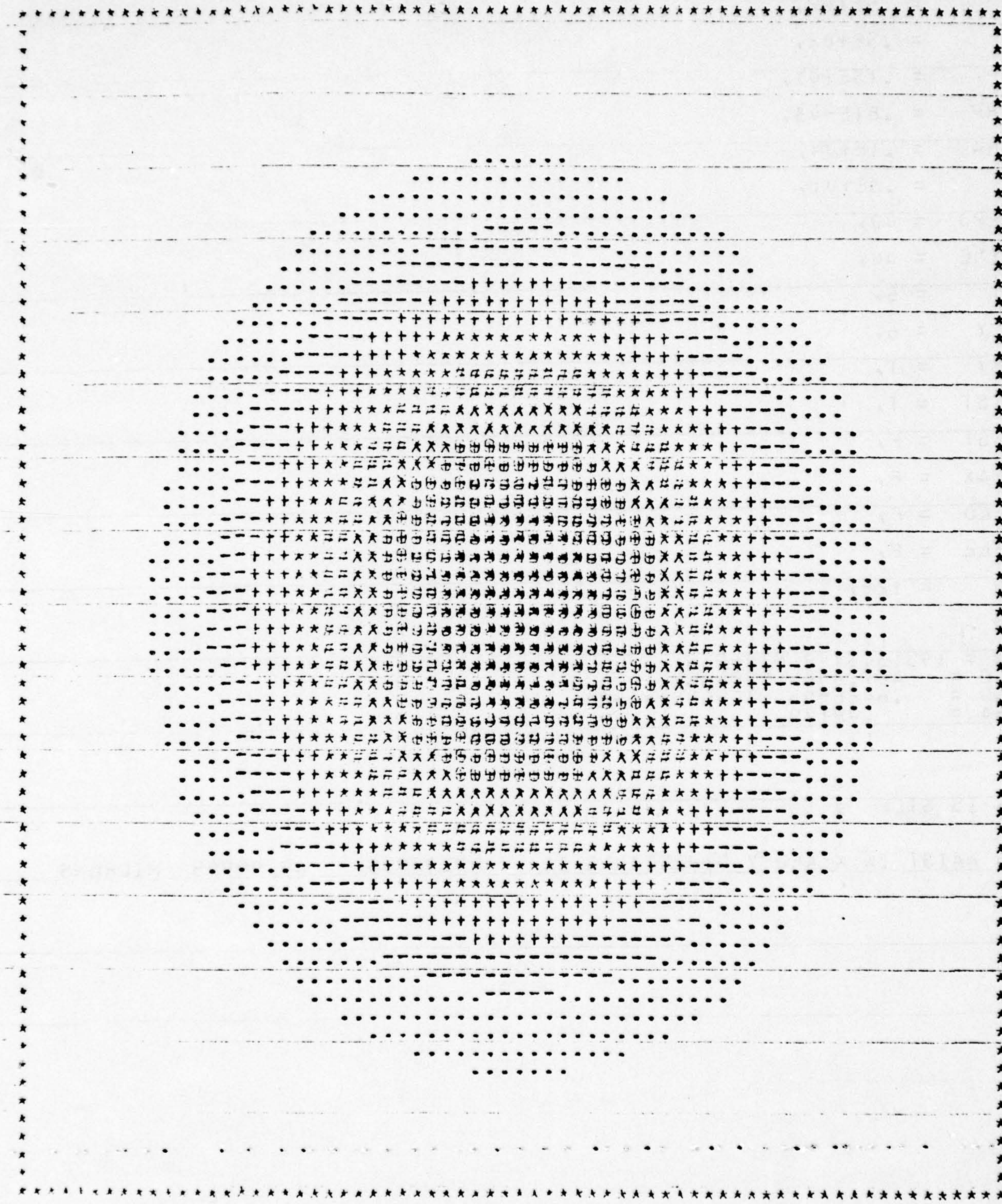
Appendix B

Fiber Taper

```
LOAD MAP - OPTFIB                                        CYBER LOADER 1.3-452          04/01/79

OSUB.RM        130206        71 SL-SYSIO     11/08/77 COMPASS   3. 4-452
OPEN.SQ        130277       257 SL-SYSIO     11/08/77 COMPASS   3. 4-452
OPEX.SQ        130556        14 SL-SYSIO     11/08/77 COMPASS   3. 4-452
/PUT.RT/       130572        11
FLBU.RM        130603        50 SL-SYSIO     11/08/77 COMPASS   3. 4-452
CLSF.SQ        130653       136 SL-SYSIO     11/08/77 COMPASS   3. 4-452
/CLSV.FO/      131011         7
CLSV.SQ        131020       137 SL-SYSIO     11/08/77 COMPASS   3. 4-452
/REW.FO/       131157         7
REW.SQ         131166        42 SL-SYSIO     11/08/77 COMPASS   3. 4-452
/GET.FO/       131230         7
/RPAR.XX/      131237         1
/GET.RT/       131240        11
GET.SQ         131251      1070 SL-SYSIO     11/08/77 COMPASS   3. 4-452
Z.SQ           132341       125 SL-SYSIO     11/08/77 COMPASS   3. 4-452
FSU.SQ     .   132466       107 SL-SYSIO     11/08/77 COMPASS   3. 4-452
/LCM2/       40000000    141000
           .
           .
       .207 CP SECONDS               150200B CM STORAGE USED                        97 TABLE MOVI

0. 0.
50. 46. 42. 38. 34. 30. 26. 22. 18. 14. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10.
10. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10.
```

```
$DFAULT
LAMBDA  = .8E+00,
RO      = .5E+02,
FR      = .5E+02,
NO      = .15E+01,
PCDRP   = .81E-03,
OUTRAD  = .1E+04,
DX      = .5E+01,
NSTEPS  = 40,
NDZINC  = 40,
IOUT    = 6,
IGREY   = 6,
PGREY   = T,
PWAIST  = T,
PLTWST  = F,
PLTMAX  = F,
PLTFLD  = F,
PLTFLE  = F,
MESH    = 128,
$END
ZMIN = 19513.3792 MICRONS
DZINC =    487.8344 MICRONS
RN2NO =    .648E-06 MICRONS**(-2)
ALPHA =       .42179
50.

THIS IS STEP  0

BEAM WAIST IN X AND Y DIRECTIONS IS    49.99995    49.99995  MICRONS
```

IRRADIANCE

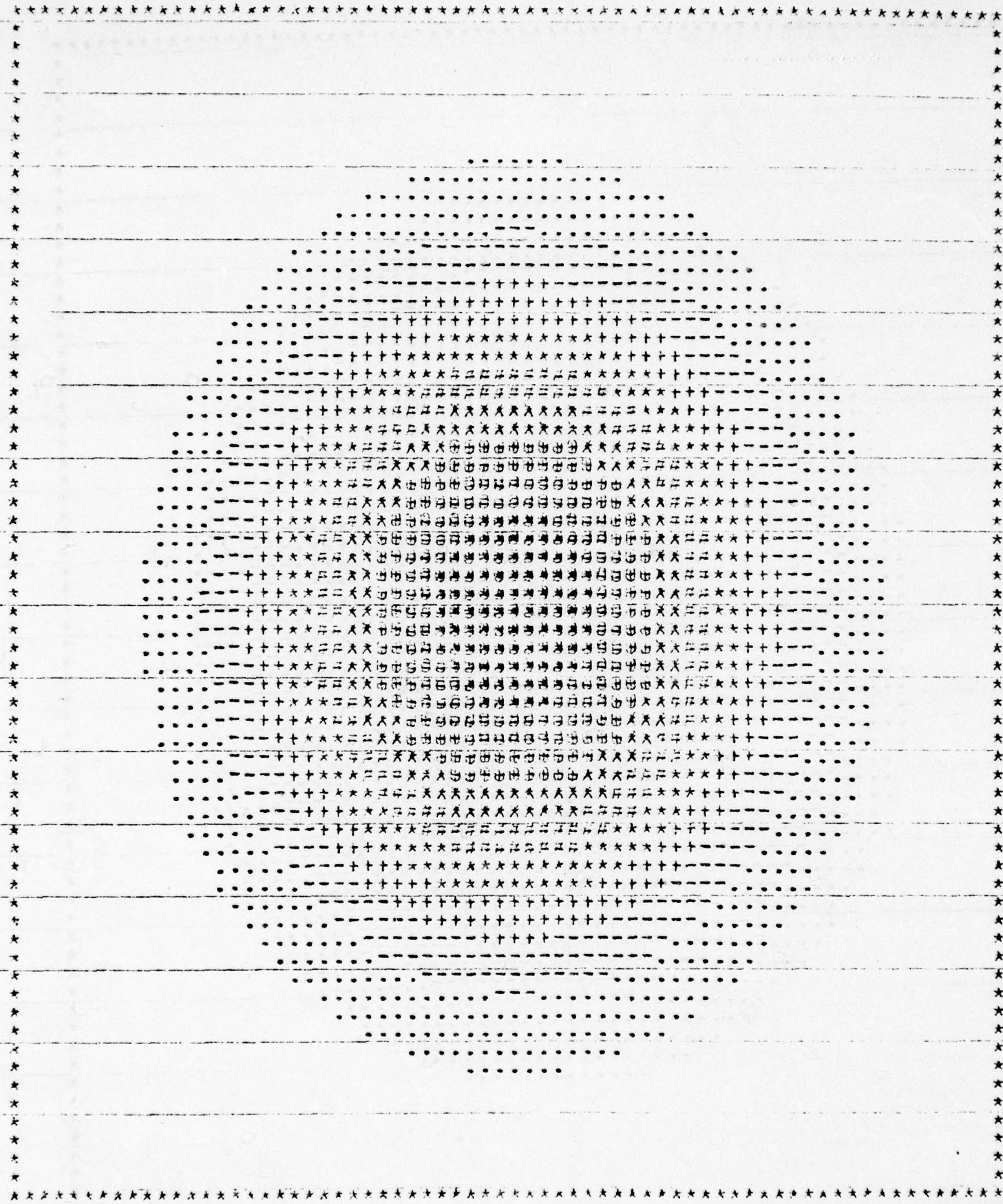


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.626107E-03	.100565E+00
.	.100565E+00	.200502E+00
-	.200502E+00	.300440E+00
+	.300440E+00	.400377E+00
*	.400377E+00	.500314E+00
=	.500314E+00	.600251E+00
X	.600251E+00	.700188E+00
#	.700188E+00	.800126E+00
[illegible]	[illegible]	[illegible]

IRRADIANCE

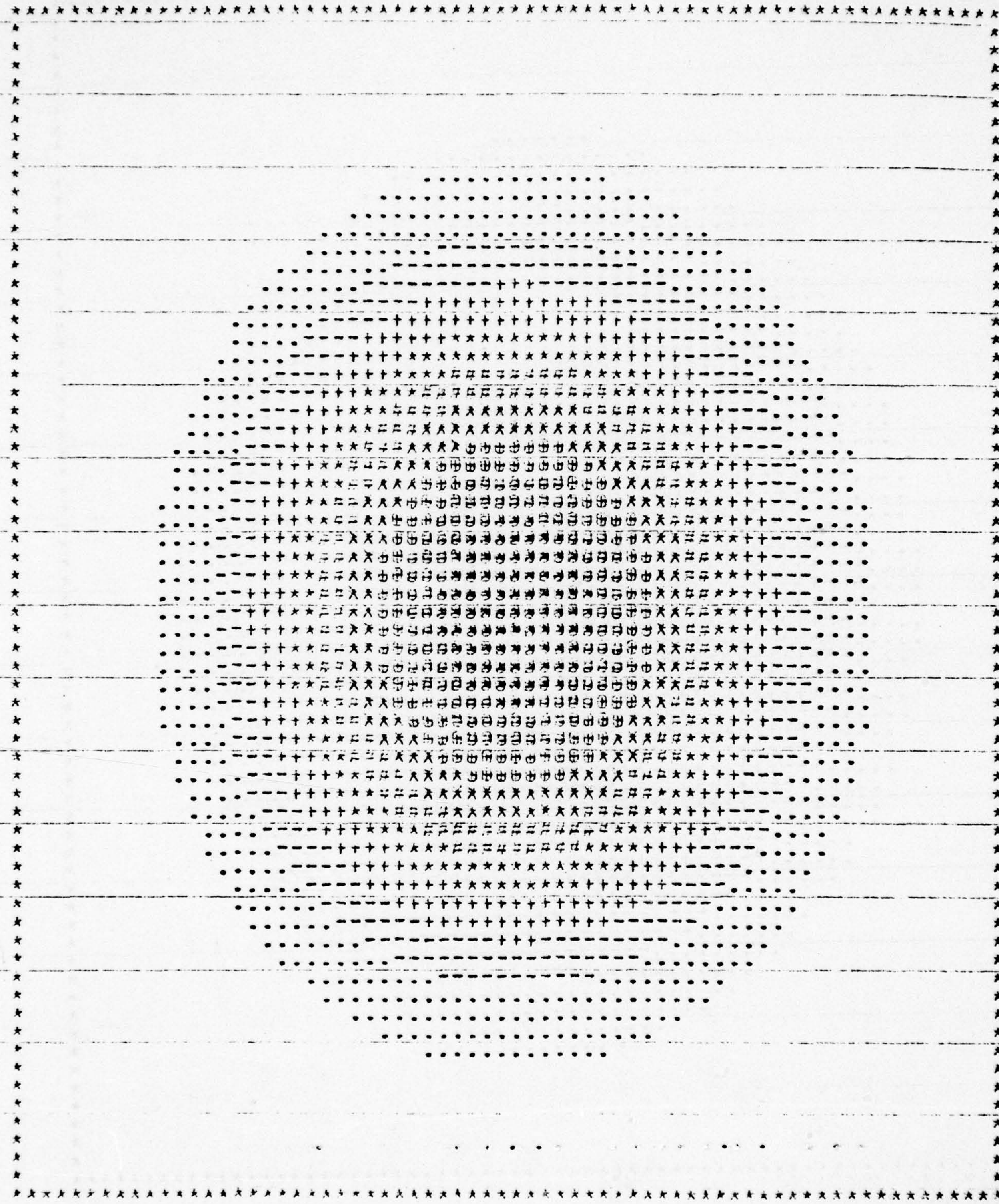


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.605562E-03	.101110E+00
.	.101110E+00	.201615E+00
-	.201615E+00	.302119E+00
+	.302119E+00	.402624E+00
*	.402624E+00	.503128E+00
=	.503128E+00	.603633E+00
X	.603633E+00	.704137E+00
@	.704137E+00	.804642E+00
[illegible]	[illegible]	[illegible]

IRRADIANCE

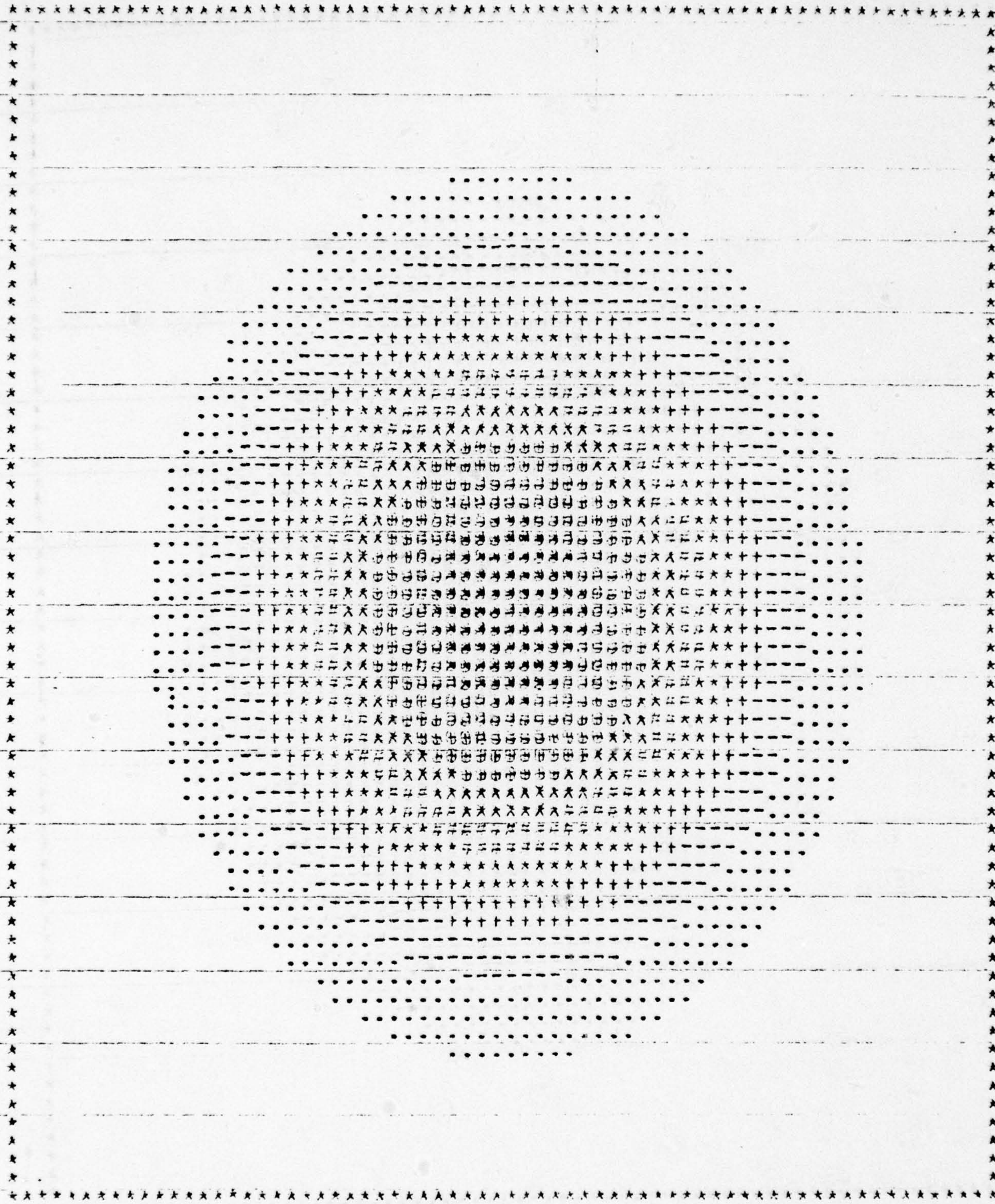


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.528309E-03	.103200E+00
.	.103200E+00	.205871E+00
-	.205871E+00	.308542E+00
+	.308542E+00	.411214E+00
*	.411214E+00	.513885E+00
=	.513885E+00	.616556E+00
X	.616556E+00	.719227E+00
⊕	.719227E+00	.821898E+00
8	.821898E+00	.924569E+00

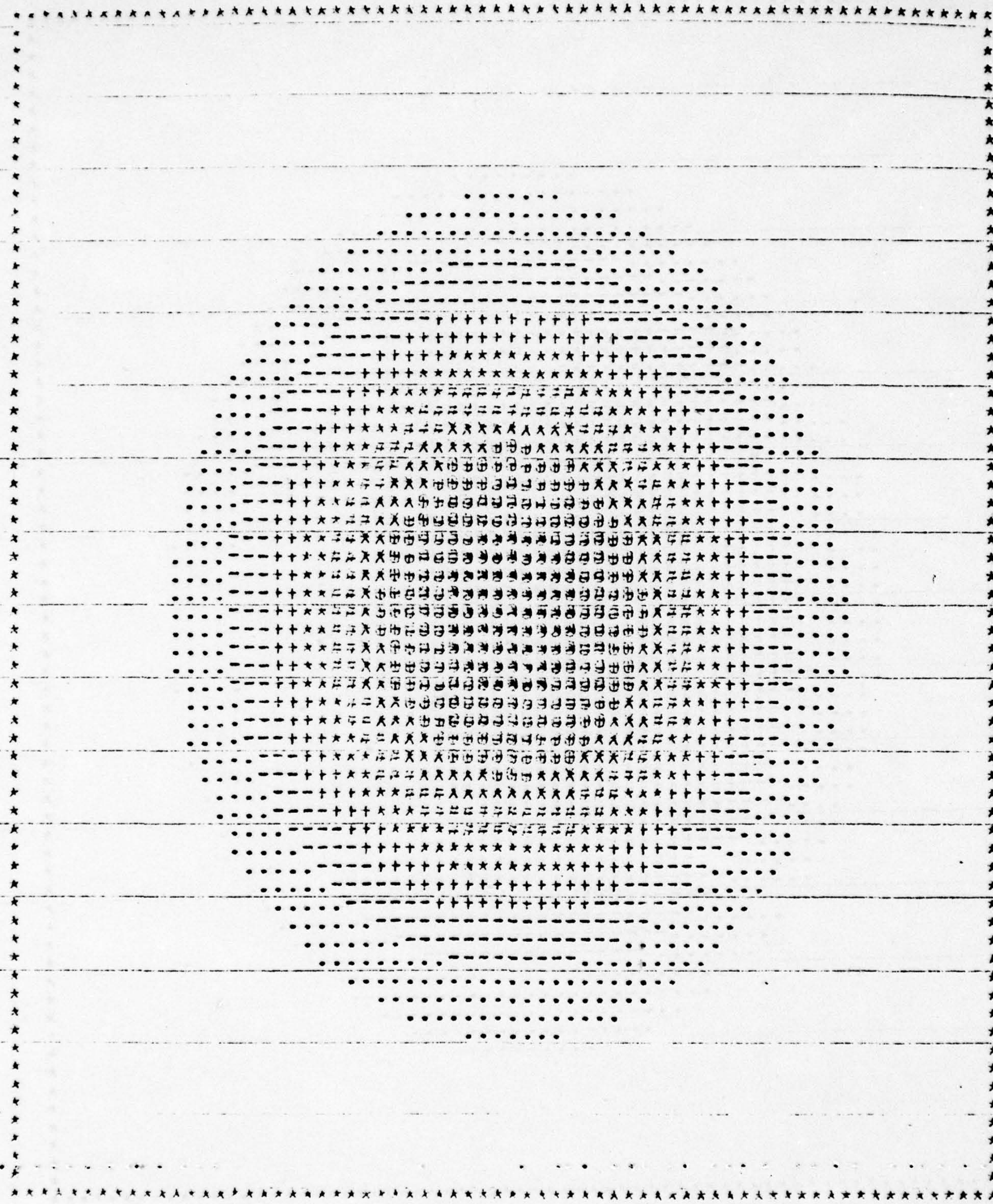
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.384330E-03	.108001E+00
.	.108001E+00	.215517E+00
-	.215517E+00	.323253E+00
+	.323253E+00	.430849E+00
*	.430849E+00	.538465E+00
=	.538465E+00	.646081E+00
X	.646081E+00	.753698E+00
#	.753698E+00	.861314E+00
B	[illegible]	

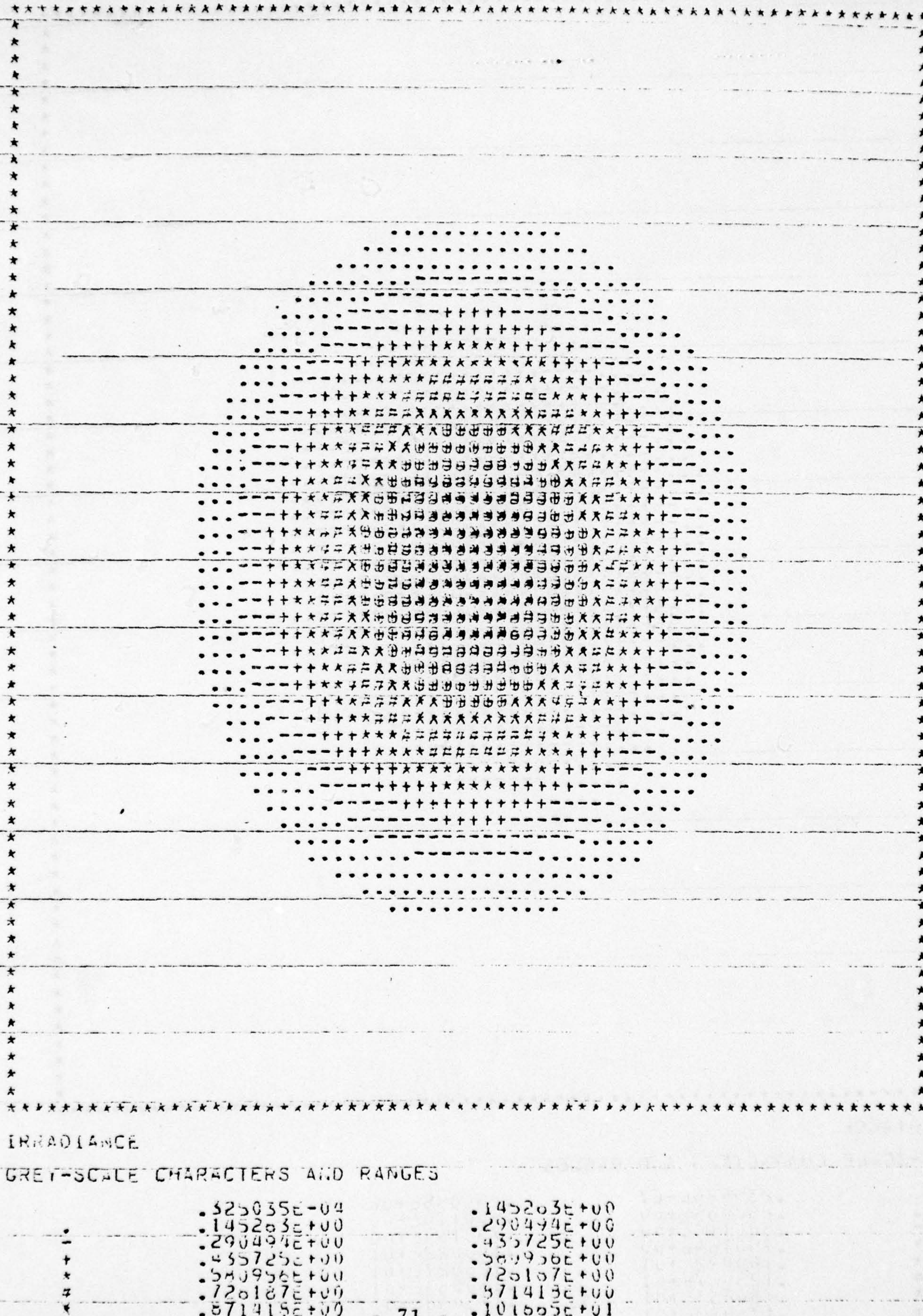


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.192622E-03	.118466E+00
.	.118466E+00	.236740E+00
-	.236740E+00	.355013E+00
+	.355013E+00	.473287E+00
*	.473287E+00	.591560E+00
=	.591560E+00	.709834E+00
X	.709834E+00	.828107E+00
⊕	.828107E+00	.946381E+00
[illegible]	.946381E+00	.106465E+01
[illegible]	[illegible]	[illegible]

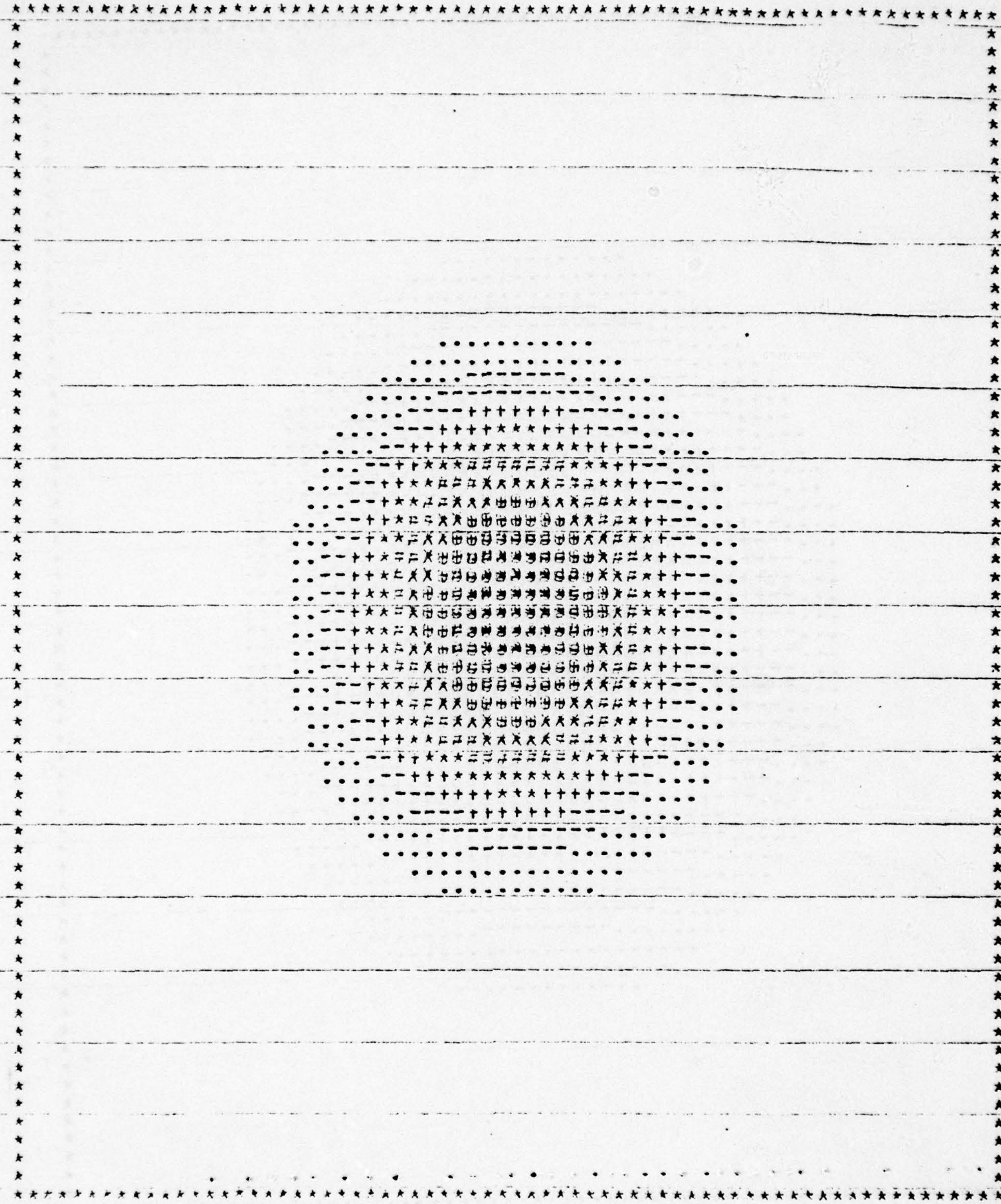
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.325035E-04	.145263E+00
.	.145263E+00	.290494E+00
-	.290494E+00	.435725E+00
+	.435725E+00	.580956E+00
*	.580956E+00	.726187E+00
#	.726187E+00	.871418E+00
X	.871418E+00	.101665E+01
⊕	.101665E+01	.116158E+01
B	[illegible]	[illegible]



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.239586E-07	.250055E+00
.	.250055E+00	.500110E+00
-	.500110E+00	.750164E+00
+	.750164E+00	.100022E+01
*	.100022E+01	.125027E+01
=	.125027E+01	.150033E+01
X	.150033E+01	.175038E+01
[illegible]	.175038E+01	.200044E+01
[illegible]	.200044E+01	.225049E+01
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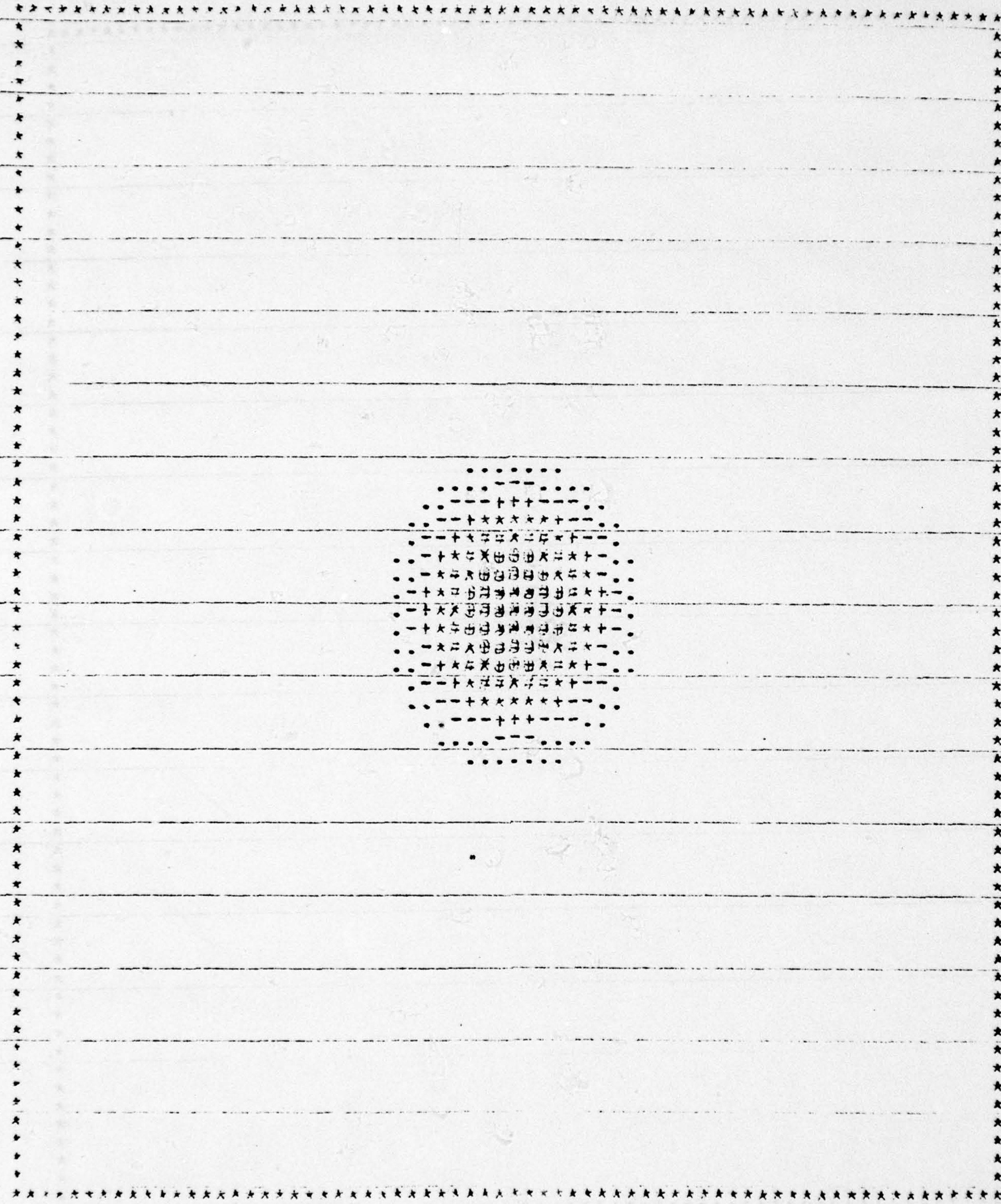
IRRADIANCE

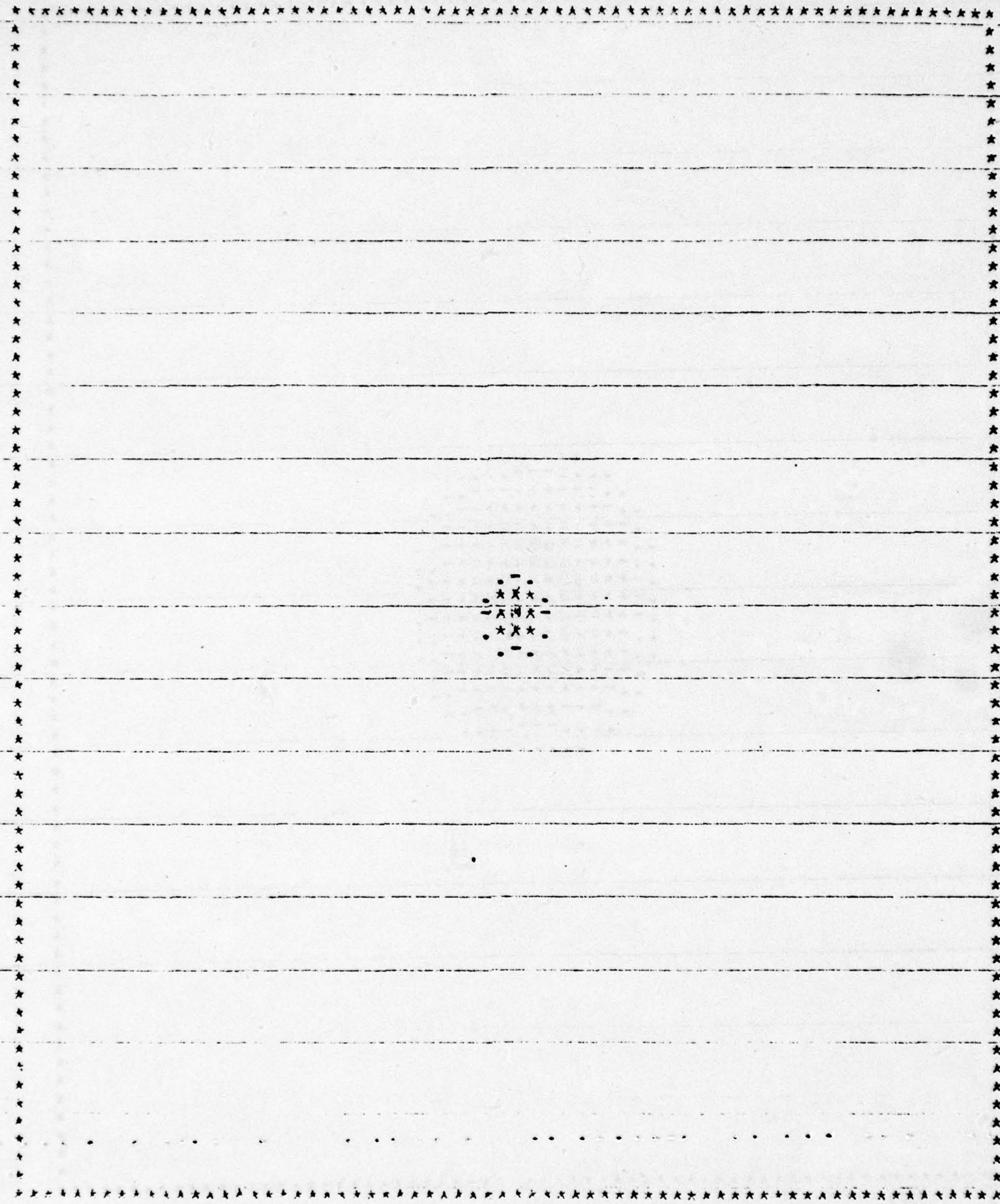


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.975260E-19	.846708E+00
.	.846708E+00	.169358E+01
-	.169358E+01	.254037E+01
+	.254037E+01	.338715E+01
*	.338715E+01	.423394E+01
=	.423394E+01	.508073E+01
X	.508073E+01	.592752E+01
@	[illegible]	[illegible]

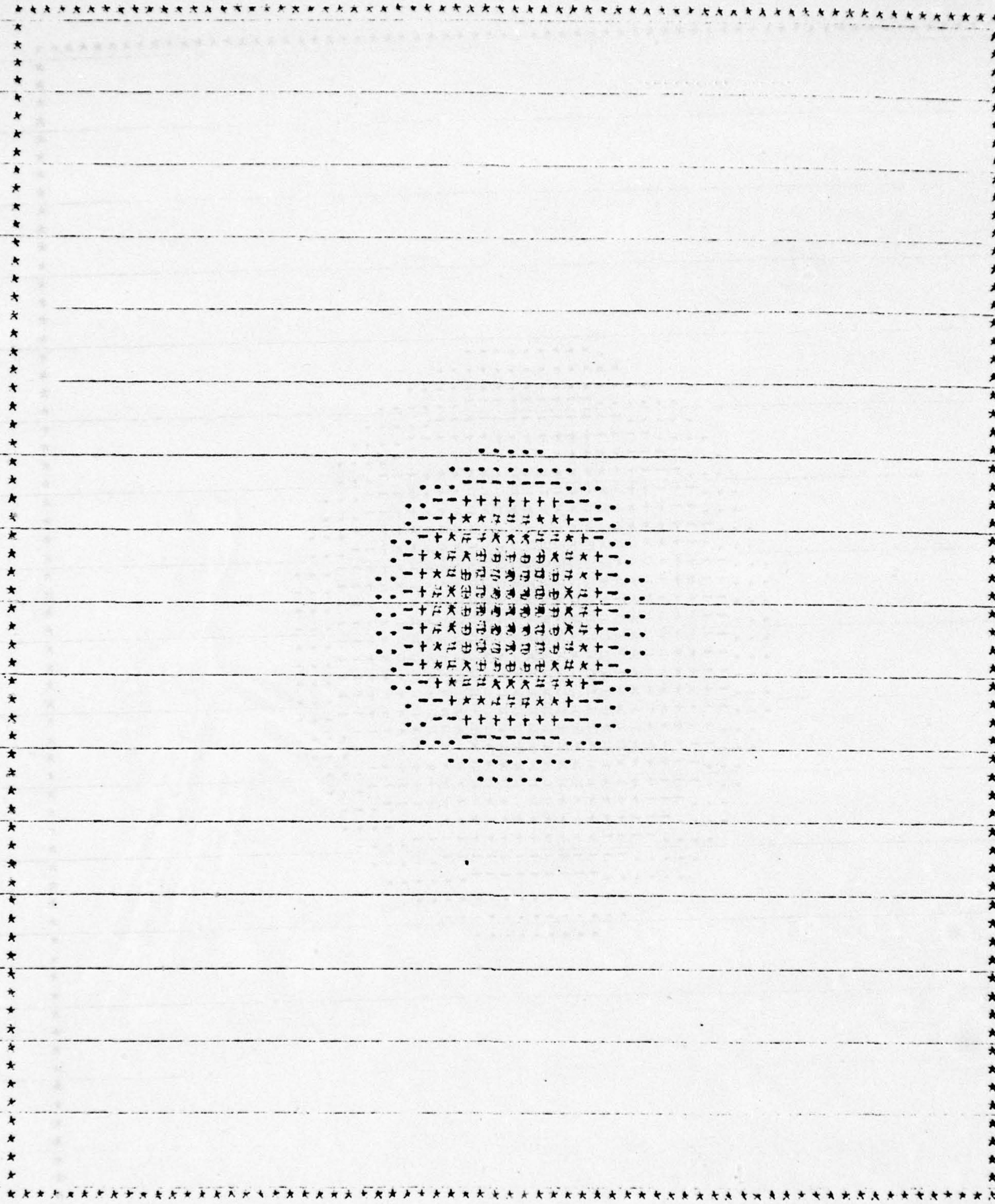
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.247612E-16	.110759E+02
.	.110759E+02	.221478E+02
-	.221478E+02	.332217E+02
+	.332217E+02	.442957E+02
*	.442957E+02	.553696E+02
=	.553696E+02	.664435E+02
X	.664435E+02	.775174E+02
#	.775174E+02	.885913E+02
H	.885913E+02	.996652E+02

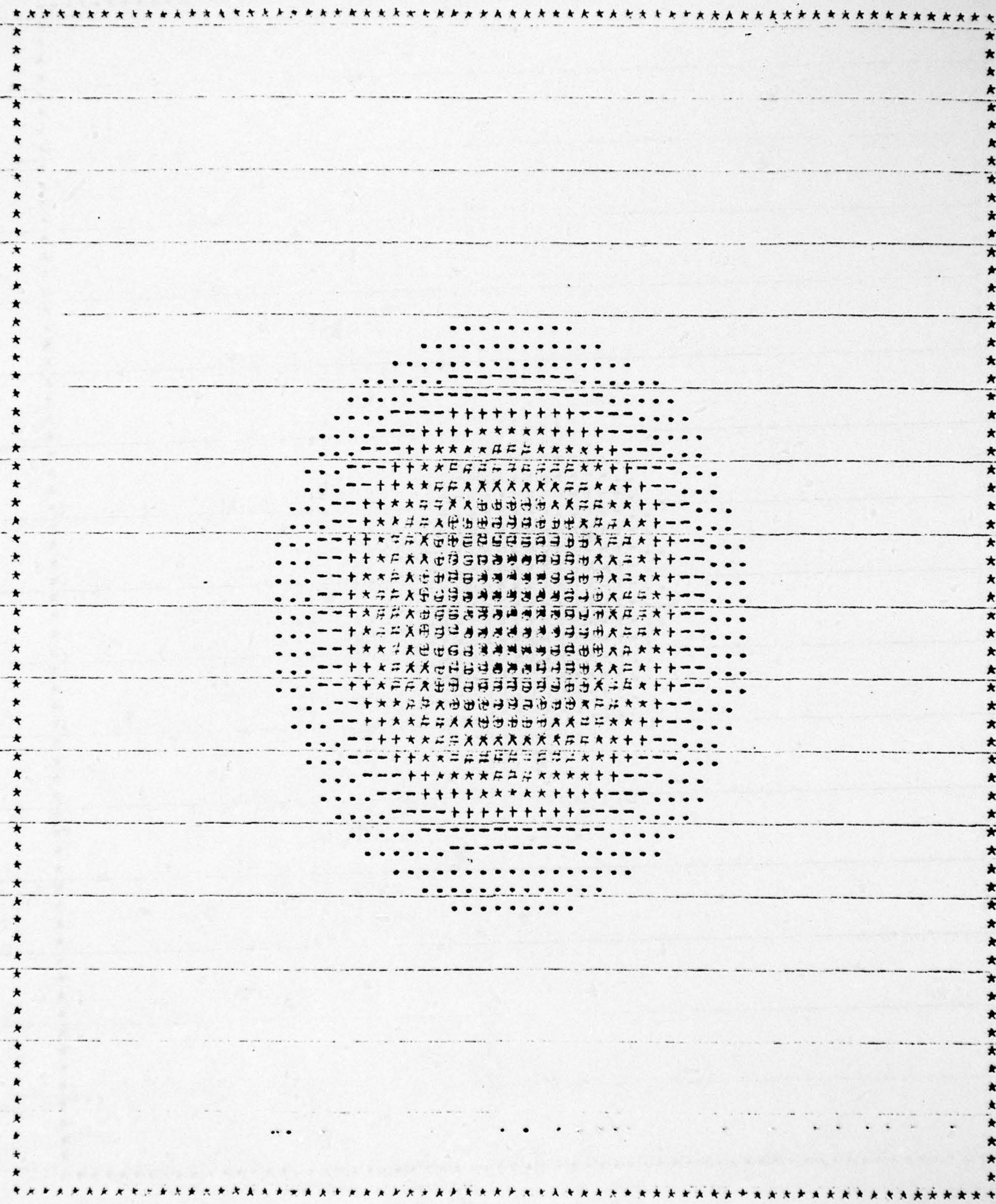


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.797534E-15	.730691E+00
.	.730691E+00	.146138E+01
-	.146138E+01	.219207E+01
+	.219207E+01	.292277E+01
*	.292277E+01	.365346E+01
=	.365346E+01	.438415E+01
X	.438415E+01	.511484E+01
#	.511484E+01	.584553E+01
[illegible]	[illegible]	[illegible]

IRRADIANCE

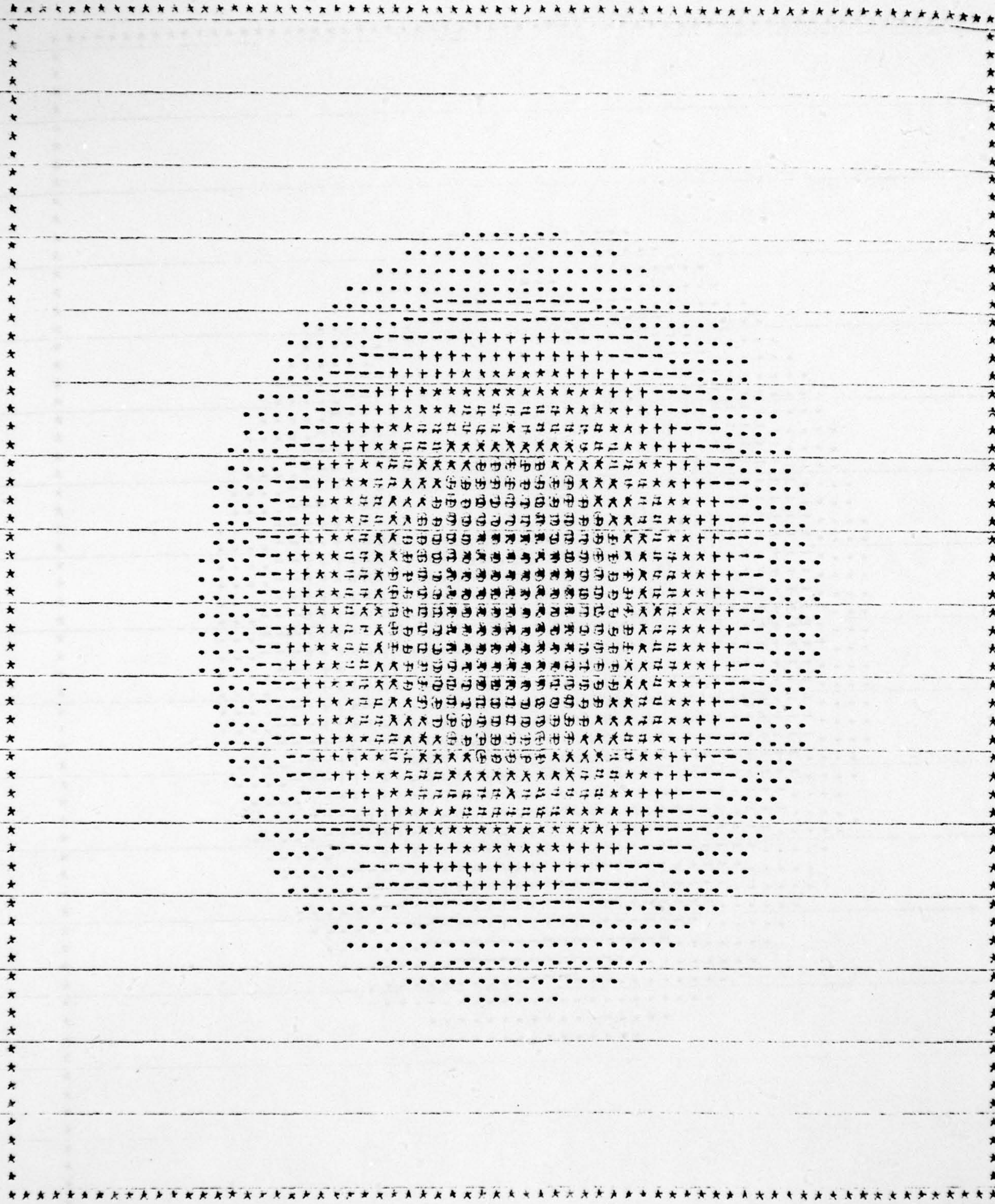


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.704617E-07	.234518E+00
.	.234518E+00	.469036E+00
-	.469036E+00	.703554E+00
+	.703554E+00	.938072E+00
*	.938072E+00	.117259E+01
=	.117259E+01	.140711E+01
X	.140711E+01	.164163E+01
⊕	.164163E+01	.187614E+01
#	.187614E+01	.211066E+01

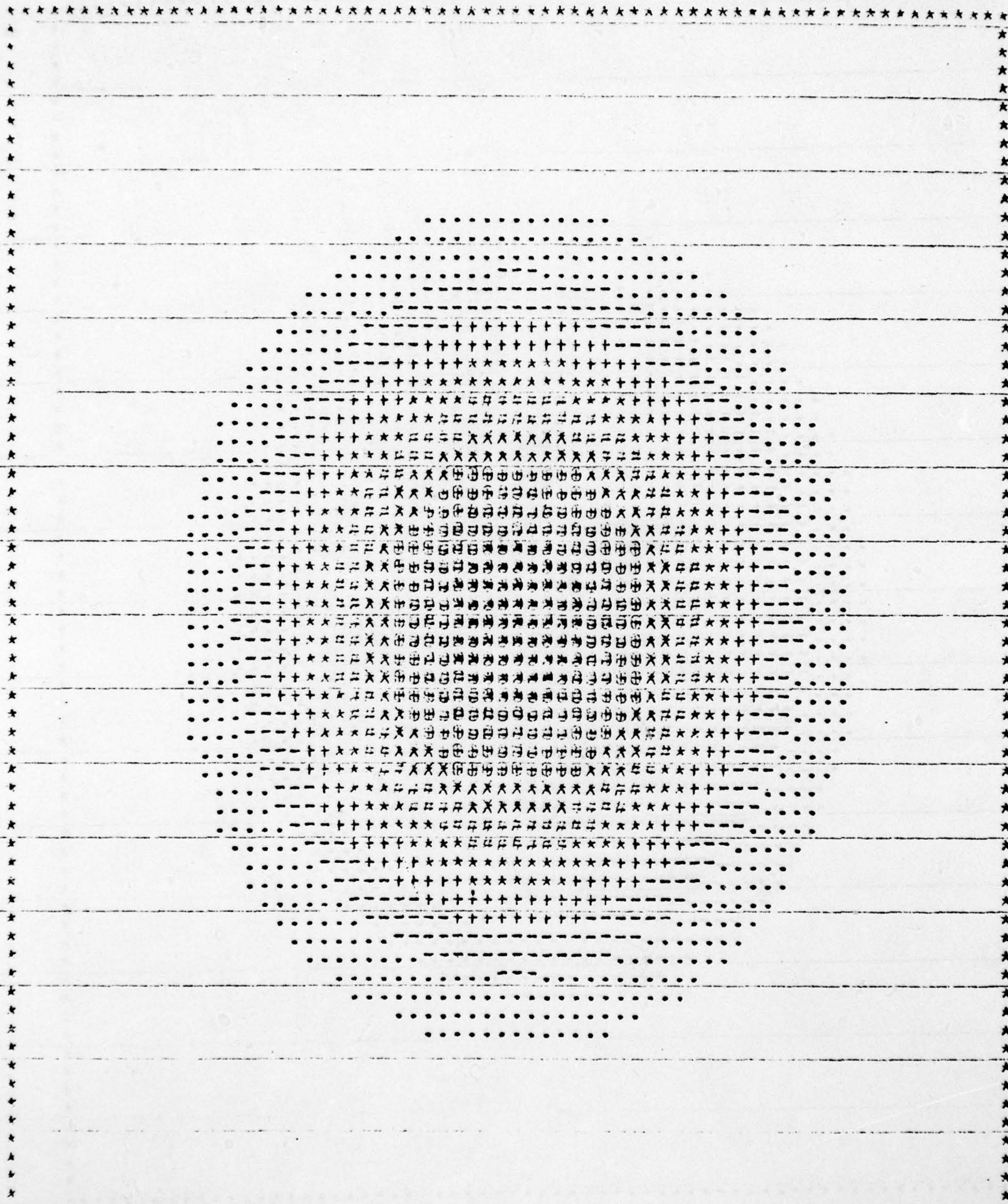
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.415876E-04	.141367E+00
.	.141367E+00	.282692E+00
-	.282692E+00	.424017E+00
+	.424017E+00	.565342E+00
*	.565342E+00	.706667E+00
=	.706667E+00	.847992E+00
X	.847992E+00	.989317E+00
8	.989317E+00	.113064E+01
θ	.113064E+01	.127197E+01
#	[illegible]	[illegible]

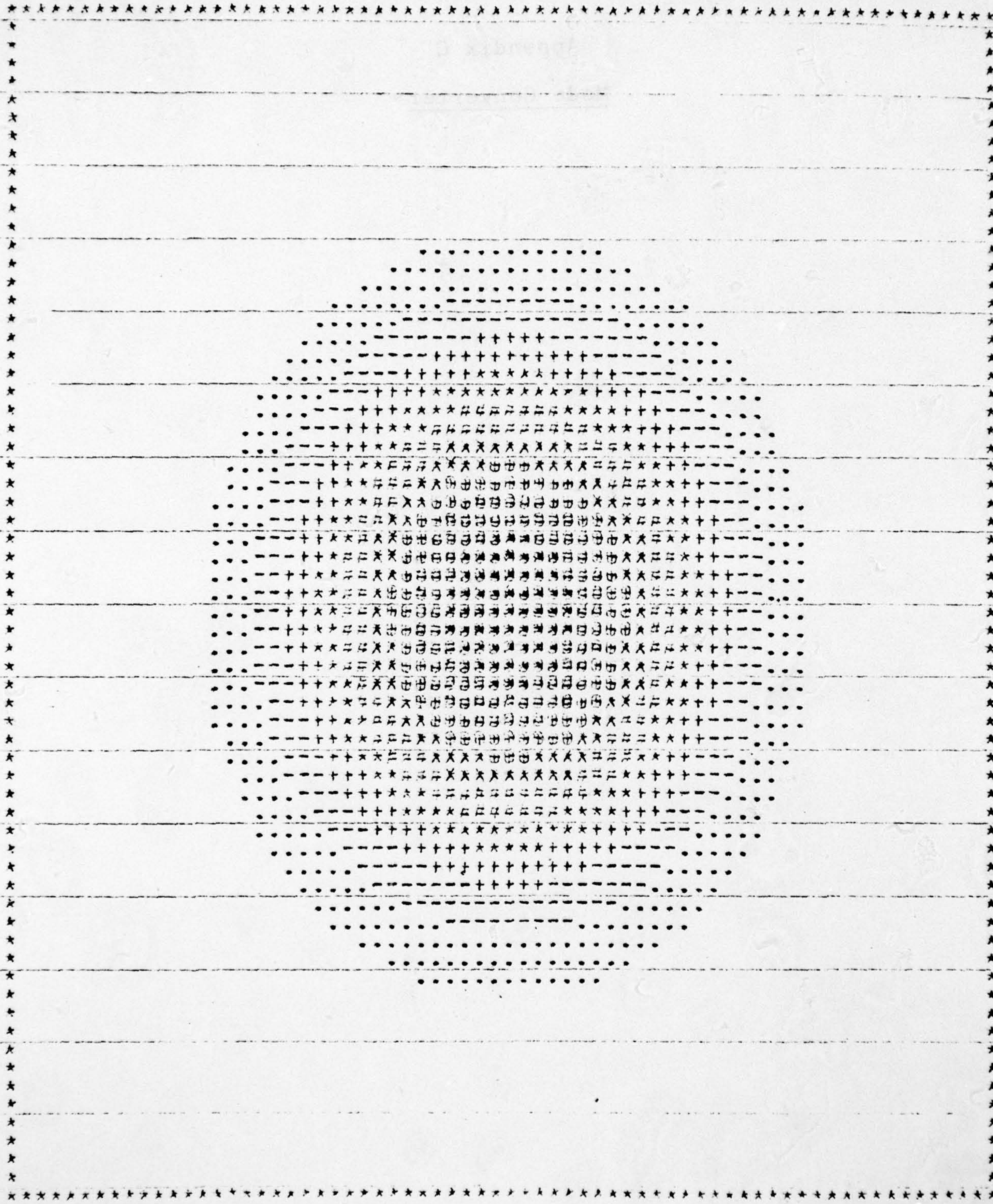


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.1452646E-03	.122854E+00
.	.122854E+00	.245562E+00
-	.245562E+00	.368270E+00
+	.368270E+00	.490978E+00
*	.490978E+00	.613686E+00
=	.613686E+00	.736395E+00
X	.736395E+00	.859103E+00
⊕	.859103E+00	.981811E+00
Θ	.981811E+00	.110452E+01
M	.110452E+01	.122723E+01

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.314935E-04	.145895E+00
.	.145895E+00	.291759E+00
-	.291759E+00	.437623E+00
+	.437623E+00	.583487E+00
*	.583487E+00	.729351E+00
=	.729351E+00	.875215E+00
X	.875215E+00	.102108E+01
⊕	.102108E+01	.116694E+01
B	[illegible]	[illegible]

Appendix C

Mode Converter

```
      PROGRAM OPTFIB(INPUT,OUTPUT,FILEO,TAPE5=INPUT,TAPE6=OUTPUT,             OPTFIB
     + TAPE7=FILEO)                                                           OPTFIB
C*****************************************************************            OPTFIB
C     INPUT PARAMETERS                                                        OPTFIB
C CARD 1 (I5 FORMAT)                                                          OPTFIB
C     NCASES   NUMBER OF CASES TO BE READ                                     OPTFIB
C CARD 2 (NAMELIST FORMAT-$DFAULT $                                           OPTFIB
C     LAMBDA   WAVE LENGTH (MICRONS)                                          OPTFIB
C     RO       1/E POINT IN IRRADIANCE (MICRONS)                              OPTFIB
C     FR       FIBER RADIUS (MICRONS)                                         OPTFIB
C     NO       REFRACTIVE INDEX                                               OPTFIB
C     PCDRP    PERCENT DROP AT R=FR OF N/NO                                   OPTFIB
C     OUTRAD   OUTER RADIUS (MICRONS)                                         OPTFIB
C     DX       MESH SPACING (MICRONS)                                         OPTFIB
C     NSTEPS   NUMBER OF Z-STEPS                                              OPTFIB
C     NDZINC   LENGTH OF Z-STEP = ZMIN/NDZINC                                 OPTFIB
C     IOUT     DEVICE NUMBER FOR OUTPUT                                       OPTFIB
C     IGREY    DEVICE NUMBER FOR GREYSC OUTPUT                                OPTFIB
C     PGREY    IF TRUE PRINT IRRADIANCE PROFILE AT EACH STEP                  OPTFIB
C     PWAIST   IF TRUE WRITE 2ND MOMENTS AT EACH STEP                         OPTFIB
C     PLTWST   IF TRUE PLOT 2ND MOMENTS VS DISTANCE                           OPTFIB
C     PLTMAX   IF TRUE PLOT PEAK INTENSITY VS DISTANCE                        OPTFIB
C     PLTFLD   IF TRUE PLOT FIELD IRRAD AT END OF PROPAGATION ALONG I         OPTFIB
C     PLTFLE   IF TRUE DO ABOVE PLOT AT EVERY STEP                            OPTFIB
C     MESH     GRID SIZE (32, 64, OR 128)                                     OPTFIB
C*****************************************************************            OPTFIB
C                                                                             OPTFIB
      COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZISQ(128),PQSQ(128)          LCM2
     + ,AMPARY(16384),RADARY(16384)                                           LCM2
      LEVEL 2,REFNDX,SN,CS,ZISQ,PQSQ,AMPARY,RADARY                            LCM2
      DIMENSION WORK(256),MU(2)                                               OPTFIB
      COMMON  /ARRAYS/V(32768)                                                ARRAYS
      COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PCDRP,OUTRAD,DX,NSTEPS,        PARAM
     + NDZINC,MESHSQ,MSHSQ2,PI,WAVENM,DXSI,MS,NS,MF,NF,MSHPTS                 PARAM
      COMMON /PRNTPLT/PGREY,PWAIST,PLTWST,PLTMAX,LAST,IOUT,IGREY              PRNTPLT
     + ,PLTFLD,PLTFLE                                                         PRNTPLT
C                                                                             OPTFIB
      REAL LAMBDA,NO,NOSQ,N2                                                  OPTFIB
      LOGICAL PGREY,PWAIST,PLTWST,PLTMAX,PLTFLD,PLTFLE,LAST,CALLPR            OPTFIB
C                                                                             OPTFIB
      DATA PI/3.14159265/,ICNTCS/1/,ICNT/0/                                   OPTFIB
C                                                                             OPTFIB
      NAMELIST /DFAULT/LAMBDA,RO,FR,NO,PCDRP,OUTRAD,DX,NSTEPS,NDZINC,         OPTFIB
     + IOUT,IGREY,PGREY,PWAIST,PLTWST,PLTMAX,PLTFLD,PLTFLE,MESH               OPTFIB
C                                                                             OPTFIB
      READ(5,1000) NCASES                                                     OPTFIB
      READ(5,*) DSPX,DSPY                                                     TEMP
      WRITE(6,*) DSPX,DSPY                                                    TEMP
 1000 FORMAT(I5)                                                              OPTFIB
 1    READ(5,DFAULT)                                                          OPTFIB
C                                                                             OPTFIB
      ICNT=0                                                                  OPTFIB
      FLAG=NO/ABS(NO)                                                         OPTFIB
      NO=ABS(NO)                                                              OPTFIB
      IF(FLAG.LT.0.) WRITE(IOUT,2050)                                         OPTFIB
 2050 FORMAT(/,47H THE REFRACTIVE INDEX IS A CONSTANT EQUAL TO NO)            OPTFIB
      WRITE(IOUT,DFAULT)                                                      OPTFIB
```

```
C
C     CALCULATE CONSTANTS
C
      MESH2=2*MESH
      MESHSQ=MESH**2
      MSHSQ2=2*MESHSQ
      RN2NO=.02*PCORP/FR**2
      ZMIN=PI/(2.*SQRT(RN2NO))
      DZINC=ZMIN/NDZINC
      DXSI=DZINC/ZMIN
      DXSIH=DXSI/2.
      DZET=DX/RO
      WAVENM=2.*PI/LAMBDA
      BETAHT=(2.*ZMIN*DXSI/(WAVENM*NO))*(PI/(MESH*DZET*RO))**2
      FTCNST=(1.-1./MESH)*PI
      XYO=MESH/2.
      RADNRM=(OUTRAD/RO)**2
      RNORM=1./MESHSQ
      N2=NO*RN2NO
      REFCF=N2*RO**2/2.
      ALPHA=2.*ZMIN/(PI*WAVENM*NO*RO**2)
      NOSQ=NO**2
      MU(1)=MESH
      MU(2)=MESH
      XSIMUL=DXSI
      LAST=.F.
      IF(FLAG.LT.0.) REFCF=0.
      CALLPR=PGREY.OR.PWAIST.OR.PLTWST.OR.PLTMAX.OR.PLTFLD.OR.PLTFLE
C
C     WRITE THE IMPORTANT CALCULATED PARAMETERS
C
      WRITE(IOUT,2000) ZMIN,DZINC,RN2NO,ALPHA
 2000 FORMAT(/,8H ZMIN = ,F10.4,1X,7HMICRONS,/,9H DZINC = ,F10.4,1X,
     + 7HMICRONS,/,9H RN2NO = ,E10.3,1X,13HMICRONS**(-2),/,
     + 9H ALPHA = ,F10.5,/)
C
C     CALCULATE NECESSARY ARRAYS
C
      DO 100 K=1,MESH
      RK=K-1
      ARG=FTCNST*RK
      CS(K)=COS(ARG)
      SN(K)=SIN(ARG)
      ZTSQ(K)=((RK-XYO)*DZET)**2
      POSQ(K)=(RK-XYO+.5)**2
  100 CONTINUE
C
C     SET UP REFRACTIVE INDEX ARRAY
C
      IF(MESH.NE.128) GO TO 10
      MS=MESH/4+1
      MF=MS+MESH/2-1
      NS=MS
      NF=MF
      GO TO 40
   10 CONTINUE
      MS=1
```

```
      NS=1
      MF=MESH
      NF=MESH
   40 CONTINUE
      CALL RINDEX(DSPX,DSPY,NOSJ,DZET,XYO,REFCF,1)
C
C     SET UP INITIAL FIELD
C
      M=-1
      K=0
      CH=WAVENM*ZMIN*DXSIH/(2.*NO)
      DO 140 J=1,MESH
      Z1=ZTSQ(J)
      DO 140 I=1,MESH
      K=K+1
      M=M+2
      MP1=M+1
      Z2=ZTSQ(I)
      RAD=Z1+Z2
      IF(RAD.GT.RADNRM) GO TO 20
      AMP=EXP(-RAD/2.)
      ARG=CH*REFNDX(K)
      V(M)=AMP*COS(ARG)
      V(MP1)=AMP*SIN(ARG)
      GO TO 140
   20 CONTINUE
      V(M)=0.
      V(MP1)=0.
  140 CONTINUE
      IF(CALLPR) CALL PRNTER(ICNT)
C
C     DO PROPAGATION
C
      DO 500 ICNT=1,NSTEPS
C
C     CONDITION V FOR TRANSFORM
C
      K=-1
      DO 160 J=1,MESH
      SNJ=SN(J)
      CSJ=CS(J)
      DO 160 I=1,MESH
      K=K+2
      KP1=K+1
      SNI=SN(I)
      CSI=CS(I)
      AR=CSJ*CSI-SNJ*SNI
      AI=-(CSJ*SNI+CSI*SNJ)
      VR=V(K)
      VI=V(KP1)
      V(K)=VR*AR-VI*AI
      V(KP1)=VI*AR+VR*AI
  160 CONTINUE
C
C     DO TRANSFORM
C
      CALL FOURT(V,NU,2,1,1,WORK)
```

```
C                                                                       OPTFI
C     SOLVE FIRST ORDER ODE                                             OPTFI
C                                                                       OPTFI
      K=-1                                                              OPTFI
      DO 180 J=1,MESH                                                   OPTFI
      PHI1=BETAHI*POSQ(J)                                               OPTFI
      DO 180 I=1,MESH                                                   OPTFI
      K=K+2                                                             OPTFI
      KP1=K+1                                                           OPTFI
      PHI2=BETAHI*POSQ(I)                                               OPTFI
      VR=V(K)                                                           OPTFI
      VI=V(KP1)                                                         OPTFI
      ANG=-(PHI1+PHI2)                                                  OPTFI
      CANG=COS(ANG)                                                     OPTFI
      SANG=SIN(ANG)                                                     OPTFI
      V(K)=(VR*CANG-VI*SANG)*RNORM                                      OPTFI
      V(KP1)=(VR*SANG+VI*CANG)*RNORM                                    OPTFI
  180 CONTINUE                                                          OPTFI
C                                                                       OPTFI
C     DO INVERSE TRANSFORM                                              OPTFI
C                                                                       OPTFI
      CALL FOURT(V,MU,2,-1,1,WORK)                                      OPTFI
C                                                                       OPTFI
C     RECONDITION V BECAUSE OF TRANSFORM                                OPTFI
C                                                                       OPTFI
      K=-1                                                              OPTFI
      DO 200 J=1,MESH                                                   OPTFI
      SNJ=SN(J)                                                         OPTFI
      CSJ=CS(J)                                                         OPTFI
      DO 200 I=1,MESH                                                   OPTFI
      K=K+2                                                             OPTFI
      KP1=K+1                                                           OPTFI
      SNI=SN(I)                                                         OPTFI
      CSI=CS(I)                                                         OPTFI
      AR=CSJ*CSI-SNJ*SNI                                                OPTFI
      AI=CSJ*SNI+SNJ*CSI                                                OPTFI
      VR=V(K)                                                           OPTFI
      VI=V(KP1)                                                         OPTFI
      V(K)=VR*AR-VI*AI                                                  OPTFI
      V(KP1)=VR*AI+VI*AR                                                OPTFI
  200 CONTINUE                                                          OPTFI
C                                                                       OPTFI
C     NOW INCLUDE EITHER FULL STEP OR HALF STEP REFRACTIVE              OPTFI
C     INDEX EFFECTS DEPENDING ON WHERE IN THE PATH YOU ARE              OPTFI
C                                                                       OPTFI
      IF(ICNT.EQ.NSTEPS) XSIMUL=DXSIH                                   OPTFI
      K=-1                                                              OPTFI
      CH=NAVERM*ZMIN*XSIMUL/(2.*NO)                                     OPTFI
      ICNT1=ICNT+1                                                      TEMP
      CALL PINDEX(DSPX,DXPY,NOSQ,DZET,XYO,REFCF,ICNT1)                  TEMP
      DO 220 M=1,MESHSQ                                                 OPTFI
      ARG=REFNDX(M)*CH                                                  OPTFI
      AR=COS(ARG)                                                       OPTFI
      AI=SIN(ARG)                                                       OPTFI
      K=K+2                                                             OPTFI
      KP1=K+1                                                           OPTFI
      VR=V(K)                                                           OPTFI
```

```
      VI=V(KP1)
      V(K)=VR*AR-VI*AI
      V(KP1)=VR*AI+VI*AR
  220 CONTINUE
      IF(ICNT.EQ.NSTEPS) LAST=.T.
      IF(CALLPR) CALL PRNTER(ICNT)
  500 CONTINUE
C
C     CALCULATE IRRADIANCE PATTERN AND PRINT
C
      IF(PGREY) GO TO 30
      M=0
      DO 240 K=1,MSHSQ2,2
      KP1=K+1
      VR=V(K)
      VI=V(KP1)
      M=M+1
      RADARY(M)=VR**2+VI**2
  240 CONTINUE
      CALL GREYSC(IGREY,10,RADARY,MESH,MESH,NS,MF,1,NS,NF,1,0.,0.,
     + 10HIRRADIANCE,10)
   30 CONTINUE
      ICNTCS=ICNTCS+1
      IF(ICNTCS.LE.NCASES) GO TO 1
      END
```

```
SYMBOLIC REFERENCE MAP (R=1)

RY POINTS
214   OPTFIB

RIABLES    SN   TYPE           RELOCATION
105   AI        REAL                            7061   ALPHA      REAL
076   AMP       REAL                           41000   AMPARY     REAL         ARRAY
112   ANG       REAL                            7104   AR         REAL
065   ARG       REAL                            7053   BETANT     REAL
041   CALLPR    LOGICAL                         7113   CANG       REAL
067   CH        REAL                           40200   CS         REAL         ARRAY
103   CSI       REAL                            7100   CSJ        REAL
043   DSPX      REAL                            7044   DSPY       REAL
 10   DX        REAL           PARAM            7116   DXPY       REAL
 17   DXSI      REAL           PARAM            7051   DXSIH      REAL
052   DZET      REAL                               0   DZINC      REAL
045   FLAG      REAL                               4   FR         REAL
054   FTCNST    REAL                            7072   I          INTEGER
073   ICNT      INTEGER                         6672   ICNTCS     INTEGER
115   ICNT1     INTEGER                            6   IGREY      INTEGER
  5   IOUT      INTEGER        PRNTPLT          7070   J          INTEGER
063   K         INTEGER                         7101   KP1        INTEGER
  2   LAMBDA    REAL           PARAM               4   LAST       LOGICAL
7065  M         INTEGER                            1   MESH       INTEGER
 13   MESHSQ    INTEGER        PARAM            7046   MESH2      INTEGER
 22   MF        INTEGER        PARAM            7073   MF1        INTEGER
```

```
      SUBROUTINE RINDEX(DSPX,DSPY,NOSQ,DZET,XYO,REFCF,ICNT)
      COMMON /PRNTPLT/PGREY,PWAIST,PLTWST,PLTMAX,LAST,IOUT,IGREY
     + ,PLTFLD,PLTFLE
      COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PLDRP,OUTRAD,DX,NSTEPS
     + NDZINC,MESHSQ,MSHSQ2,PI,WAVENM,DXSI,MS,NS,MF,NF,MSHPTS
      COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZTSQ(128),POSQ(128)
     + ,AMPARY(16384),RADARY(16384)
      LEVEL 2,REFNDX,SN,CS,ZTSQ,POSQ,AMPARY,RADARY
      REAL LAMBDA,NO,NOSQ,N2
      AZ=.0
      CZ=REFCF*EXP(AZ*(ICNT-1))
      CONS1=1.
      CONS2=.01
      ACON1=.000
      ACON2=.01
      BCON=25./RO
      M=0
      DO 120 J=1,MESH
      Z1=ZTSQ(J)
      DO 120 I=1,MESH
      M=M+1
      Z2=ZTSQ(I)
      RAD=Z1+Z2
      REFNDX(M)=(NO-CZ*RAD)*(CONS1*EXP(-ACON1*RAD)+CONS2*EXP(-ACON2
     + *((SQRT(RAD)-BCON)**2)))
      IF(REFNDX(M).LT.1.) REFNDX(M)=1.
  120 CONTINUE
      IF(ICNT.GT.1) GO TO 125
      CALL GREYSC(IGREY,10,REFNDX,MESH,MESH,MS,MF,1,NS,NF,1,0.,0.,
     + 6HREFNDX,5)
  125 CONTINUE
      DO 130 K=1,MESHSQ
      REFNDX(K)=REFNDX(K)**2-NOSQ
  130 CONTINUE
      RETURN
      END
```

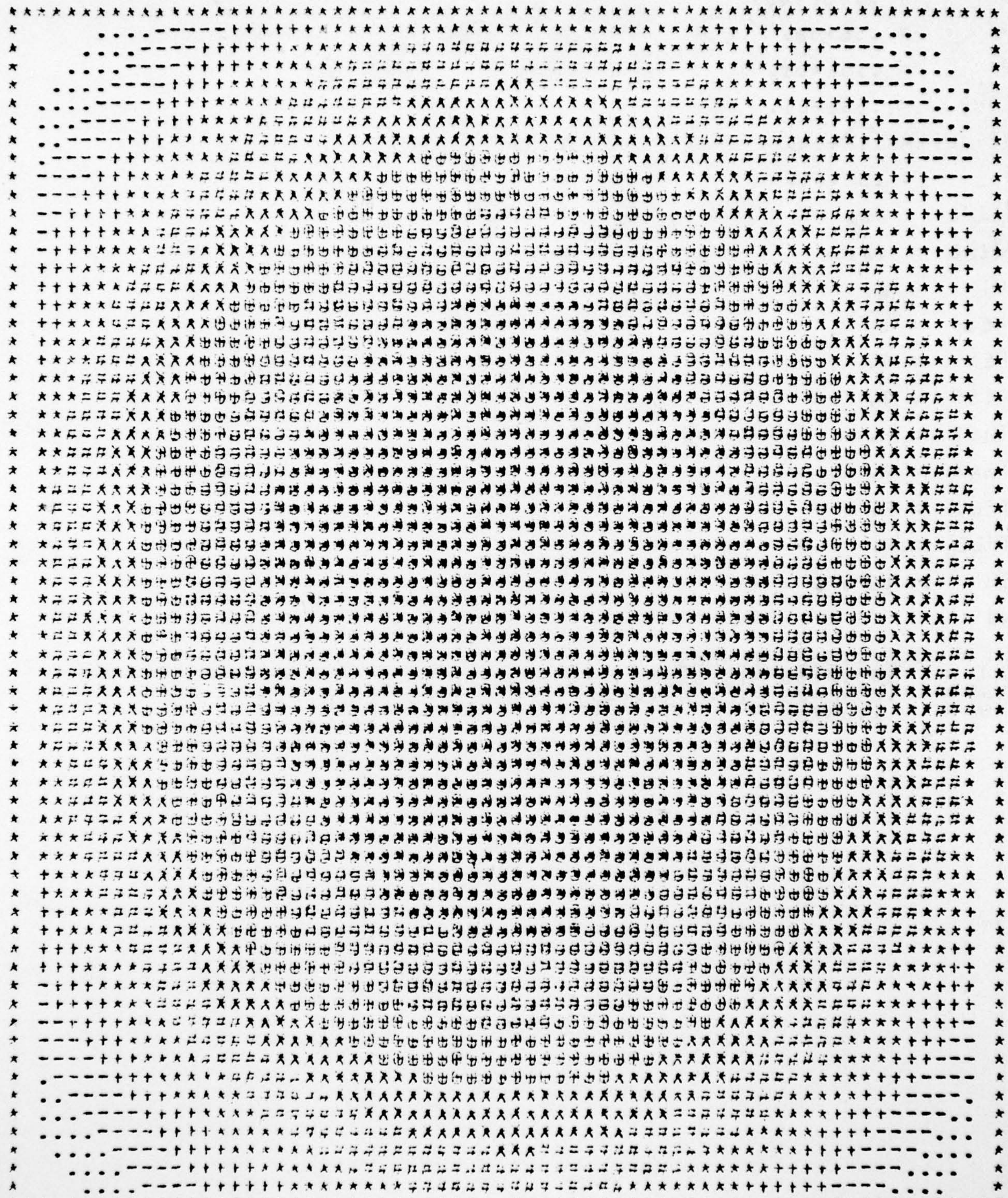
```
SYMBOLIC REFERENCE MAP (R=1)

RY POINTS
 5   RINDEX

IABLES        SN   TYPE            RELOCATION
22   ACON1         REAL                                   123   ACON2       REAL
00   AMPARY        REAL        ARRAY     LCM2             116   AZ          REAL
24   BCON          REAL                                   120   CONS1       REAL
21   CONS2         REAL                                 40200   CS          REAL         ARRAY
17   CZ            REAL                                     0   DSPX        REAL        *UNUSED
 0   DSPY          REAL       *UNUSED    F.P.              10   DX          REAL
17   DXSI          REAL                  PARAM              0   DZET        REAL        *UNUSED
 0   DZINC         REAL                  PARAM              4   FR          REAL
30   I             INTEGER                                  0   ICNT        INTEGER
 5   IGREY         INTEGER               PRNTPLT            5   IOUT        INTEGER
```

```
$DFAULT
LAMBDA   = .8E+00,
RO       = .125E+02,
FR       = .5E+02,
NO       = .15E+01,
PCORP    = .33E-01,
OUTRAD   = .1E+04,
DX       = .3E+01,
NSTEPS   = 40,
NDZINC   = 10,
IOUT     = 6,
IGREY    = 6,
PGREY    = T,
PWAIST   = T,
PLTWST   = F,
PLTMAX   = F,
PLTFLD   = F,
PLTFLE   = F,
MESH     = 128,
$END
ZMIN =   3057.1582 MICRONS
DZINC =   305.7158 MICRONS
RN2NO =  .264E-06 MICRONS**(-2)
ALPHA =     1.05730
```

REFNOX

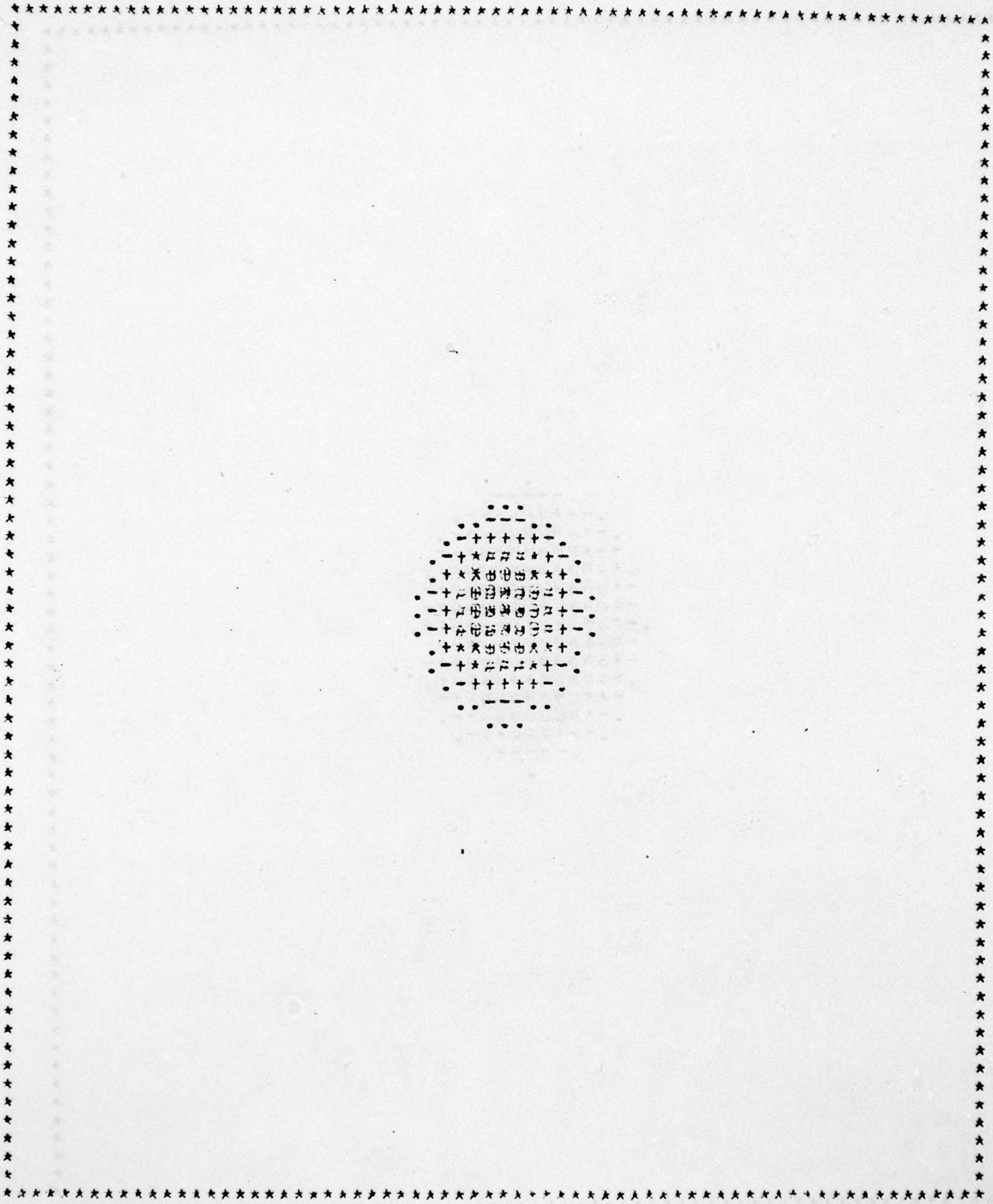


REFNOX

GREY-SCALE CHARACTERS AND RANGES

	.150317E+01	.150435E+01
.	.150435E+01	.150552E+01
-	.150552E+01	.150669E+01
+	.150669E+01	.150786E+01
*	.150786E+01	.150904E+01
=	.150904E+01	.151021E+01
X	.151021E+01	.151138E+01
⊕	.151138E+01	.151255E+01
[illegible]	.151255E+01	.151372E+01

IRRADIANCE

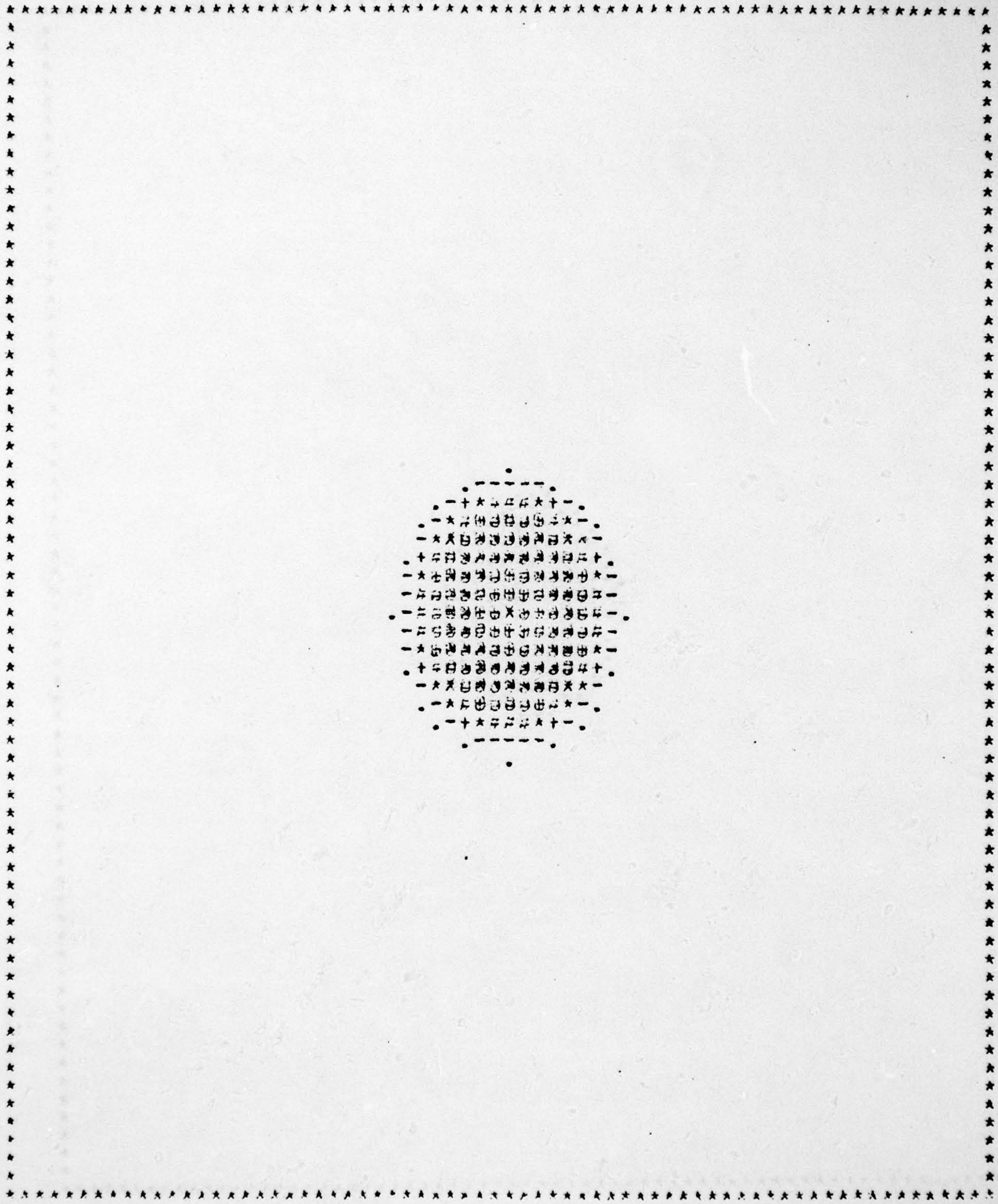


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.586865E-51	.100000E+00
.	.100000E+00	.200000E+00
-	.200000E+00	.300000E+00
+	.300000E+00	.400000E+00
*	.400000E+00	.500000E+00
=	.500000E+00	.600000E+00
X	.600000E+00	.700000E+00
[illegible]	[illegible]	

IRRADIANCE



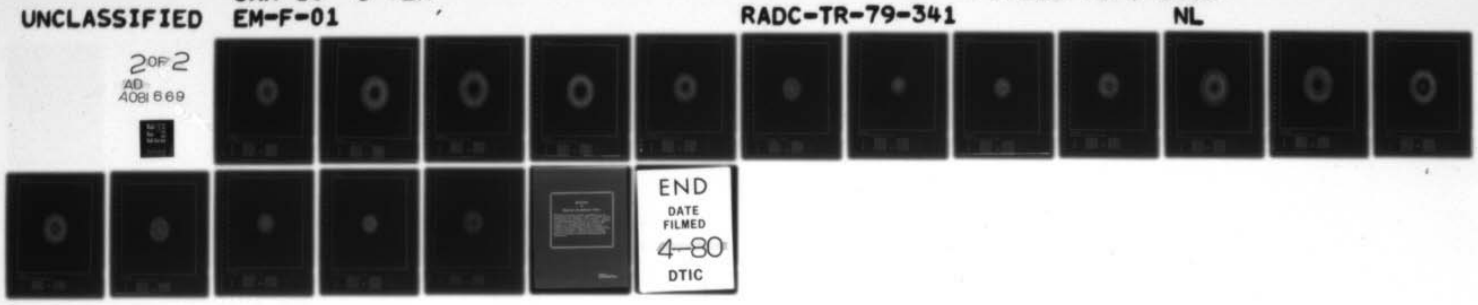
IRRADIANCE

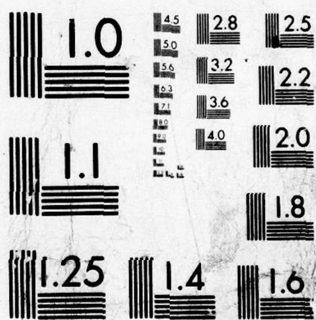
GREY-SCALE CHARACTERS AND RANGES

	.635191E-12	.442255E-01
.	.442255E-01	.884509E-01
-	.884509E-01	.132676E+00
+	.132676E+00	.176902E+00
*	.176902E+00	.221127E+00
=	.221127E+00	.265353E+00
X	.265353E+00	.309578E+00
#	.309578E+00	.353804E+00
[illegible]	.353804E+00	.398029E+00

AD-A081 669   EMTEC ENGINEERING INC LOS ANGELES CA   F/G 20/6
ANALYSIS OF MULTIMODE FIBER COUPLERS, TAPERS AND MODE CONVERTER--ETC(U)
JAN 80 C YEH   F19628-78-C-0206
UNCLASSIFIED EM-F-01   RADC-TR-79-341   NL

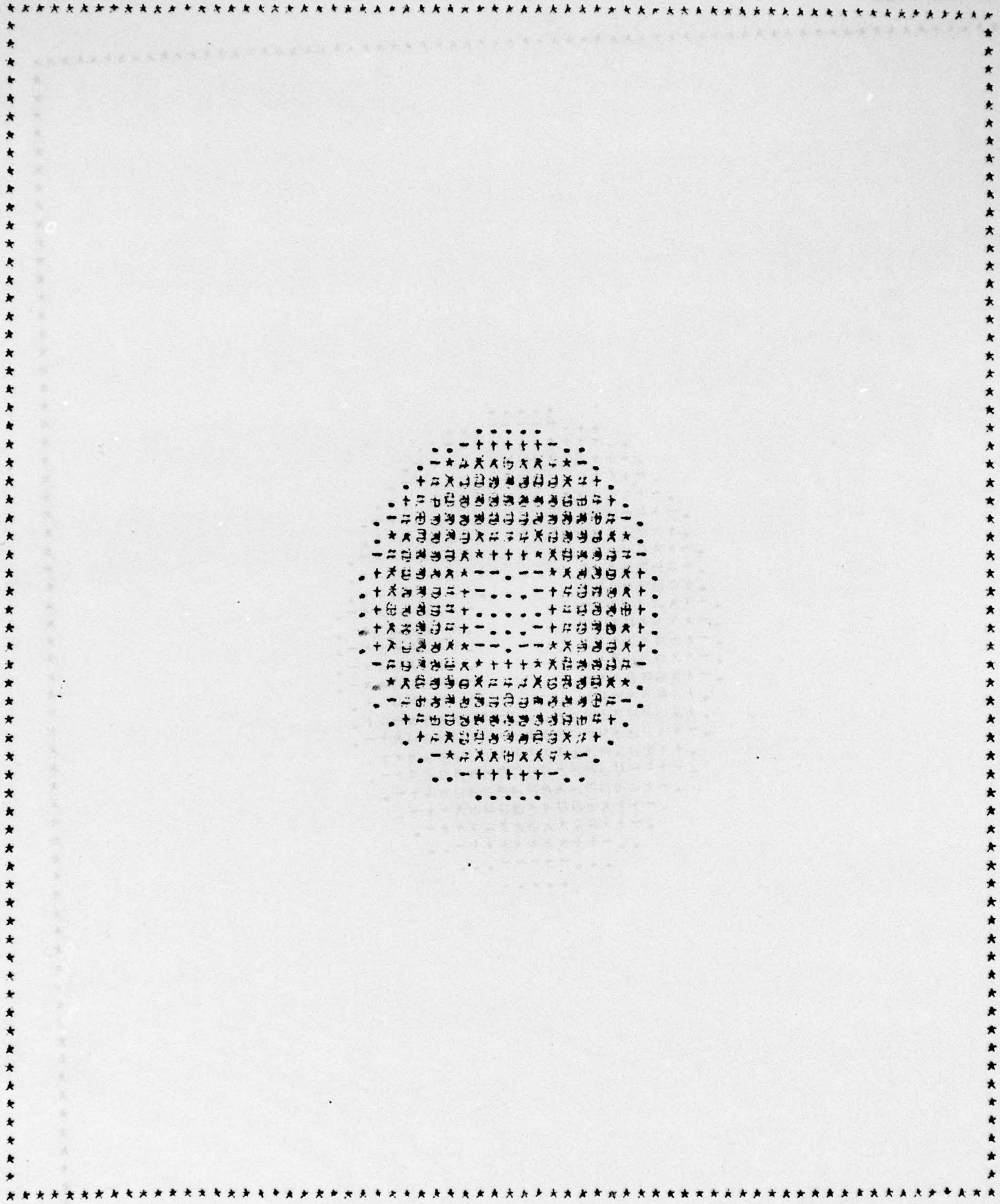
2 OF 2
AD
A081 669





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

IRRADIANCE

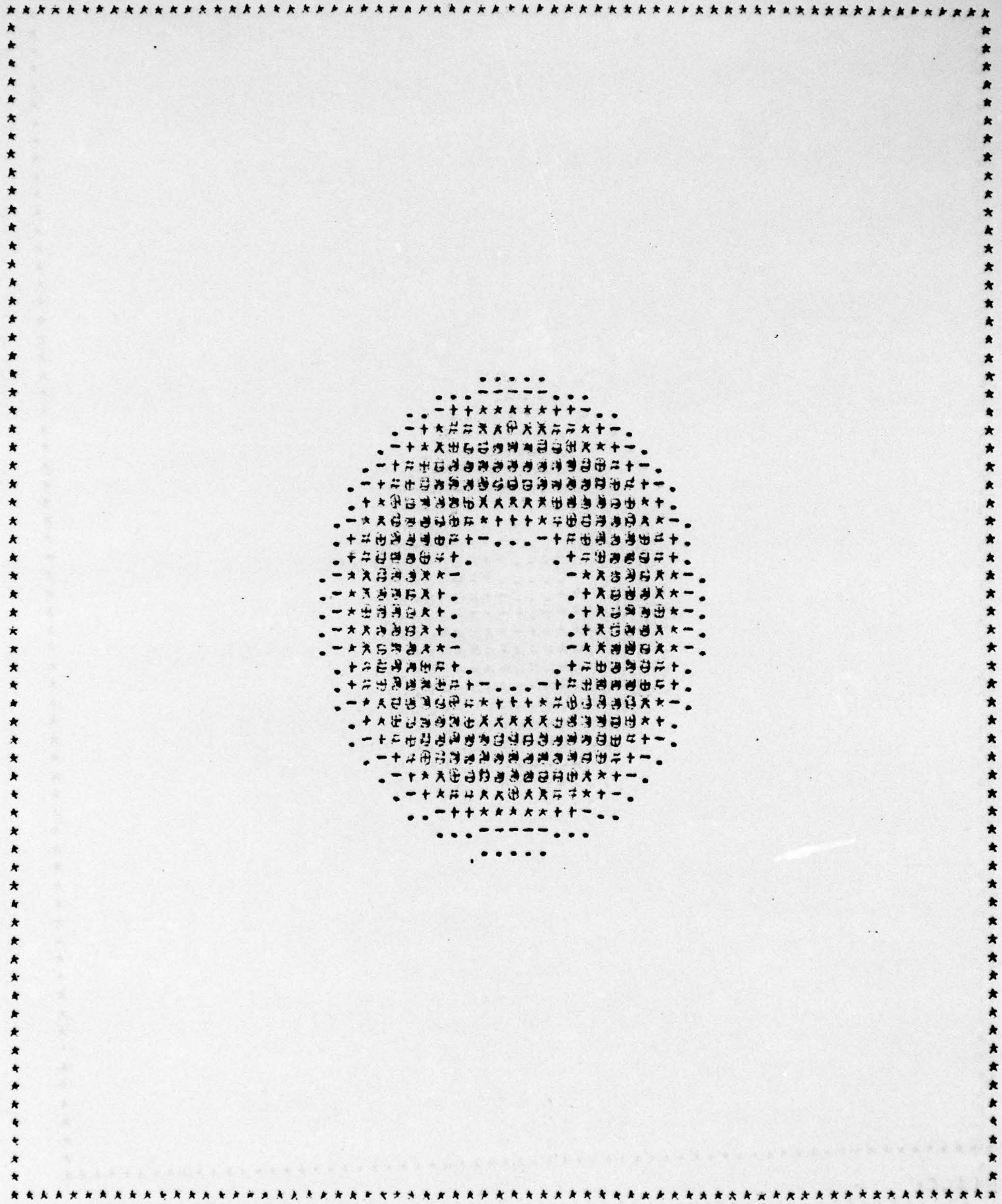


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.679915E-10	.273844E-01
.	.273844E-01	.547688E-01
-	.547688E-01	.821531E-01
+	.821531E-01	.109538E+00
*	.109538E+00	.136922E+00
=	.136922E+00	.164306E+00
X	.164306E+00	.191691E+00
0	.191691E+00	.219075E+00
@	.219079E+00	.246459E+00

IRRADIANCE

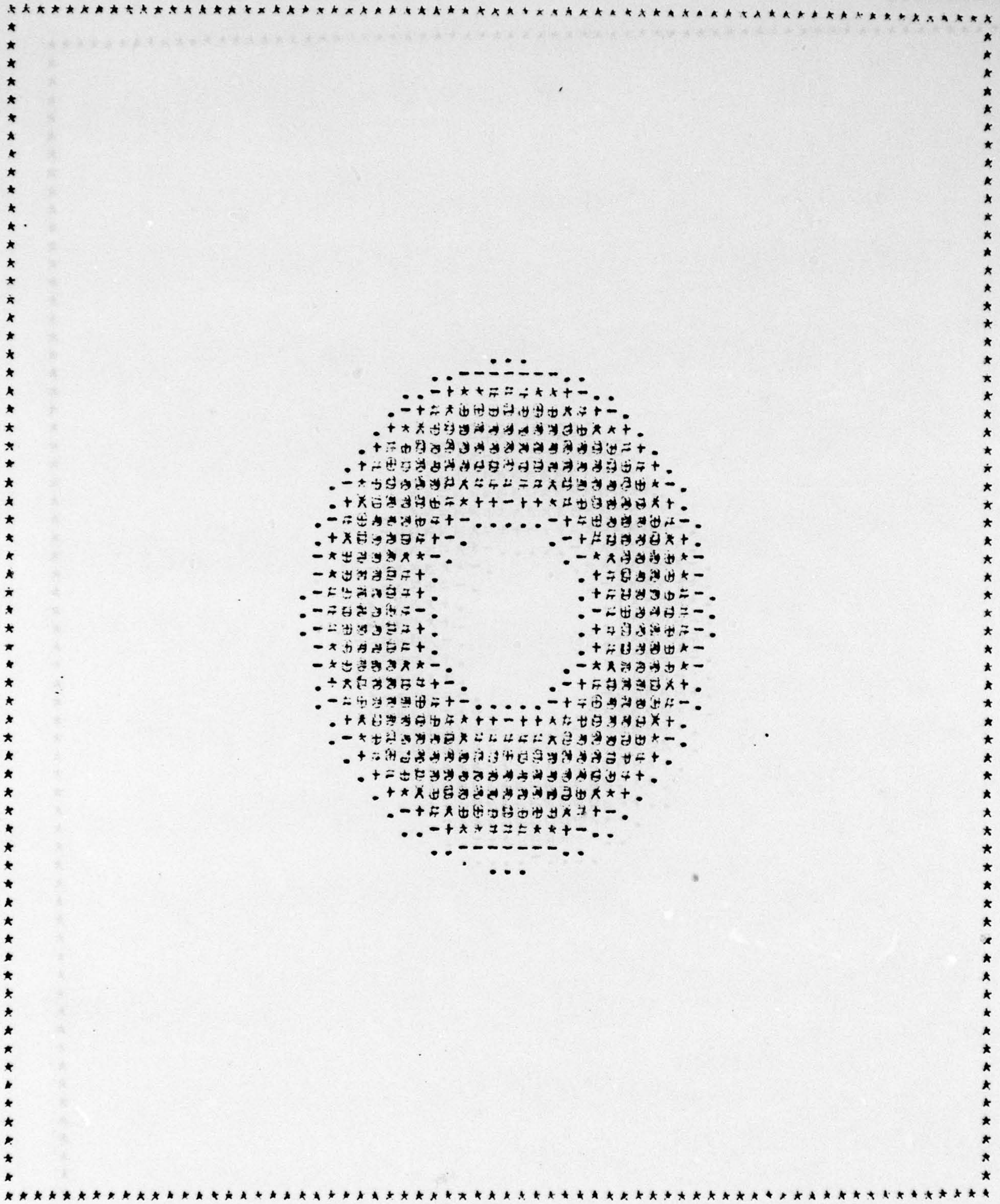


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.690653E-07	.188048E-01
.	.188048E-01	.376095E-01
-	.376095E-01	.564142E-01
+	.564142E-01	.752189E-01
*	.752189E-01	.940237E-01
=	.940237E-01	.112828E+00
X	.112828E+00	.131633E+00
⊕	.131633E+00	.150438E+00
#	.150438E+00	.169243E+00

IRRADIANCE

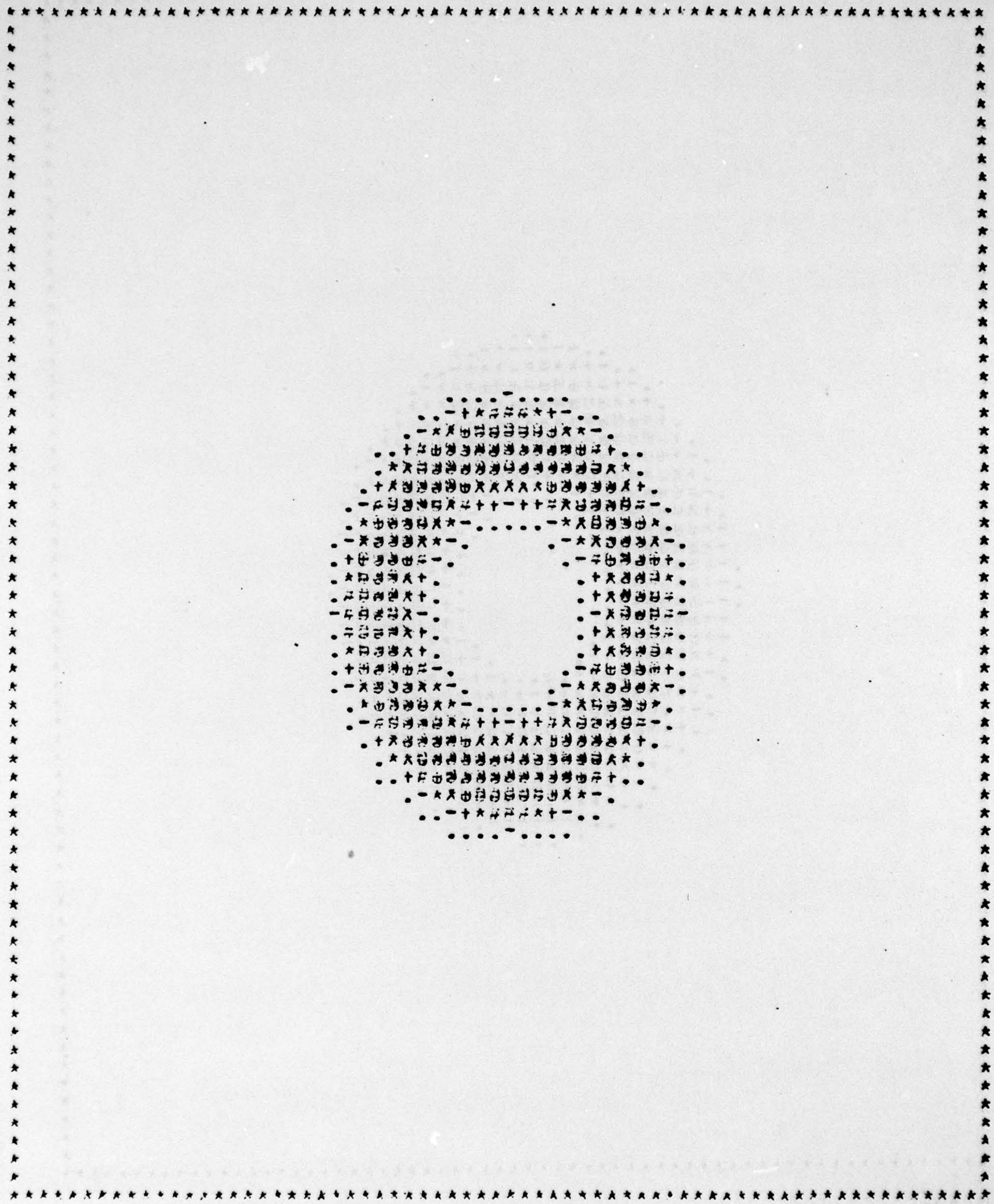


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.154550E-08	.166307E-01
.	.166307E-01	.332614E-01
-	.332614E-01	.498922E-01
+	.498922E-01	.665229E-01
*	.665229E-01	.831536E-01
#	.831536E-01	.997843E-01
X	.997843E-01	.116415E+00
@	.116415E+00	.133046E+00

IRRADIANCE

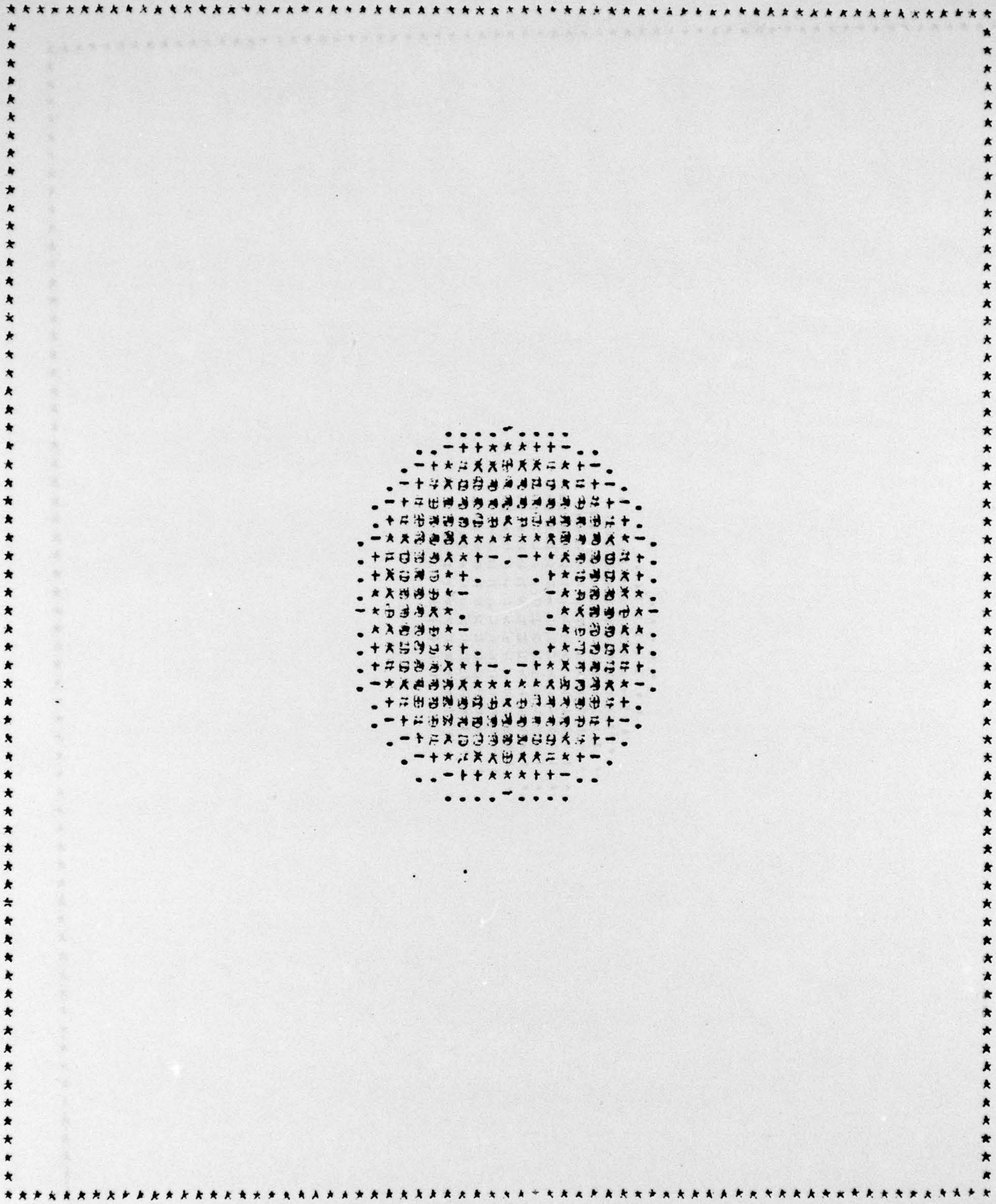


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.261062E-09	.210601E-01
.	.210601E-01	.421202E-01
-	.421202E-01	.631802E-01
+	.631802E-01	.842403E-01
*	.842403E-01	.105300E+00
#	.105300E+00	.126360E+00
X	.126360E+00	.147421E+00
@	.147421E+00	.168481E+00

IRRADIANCE

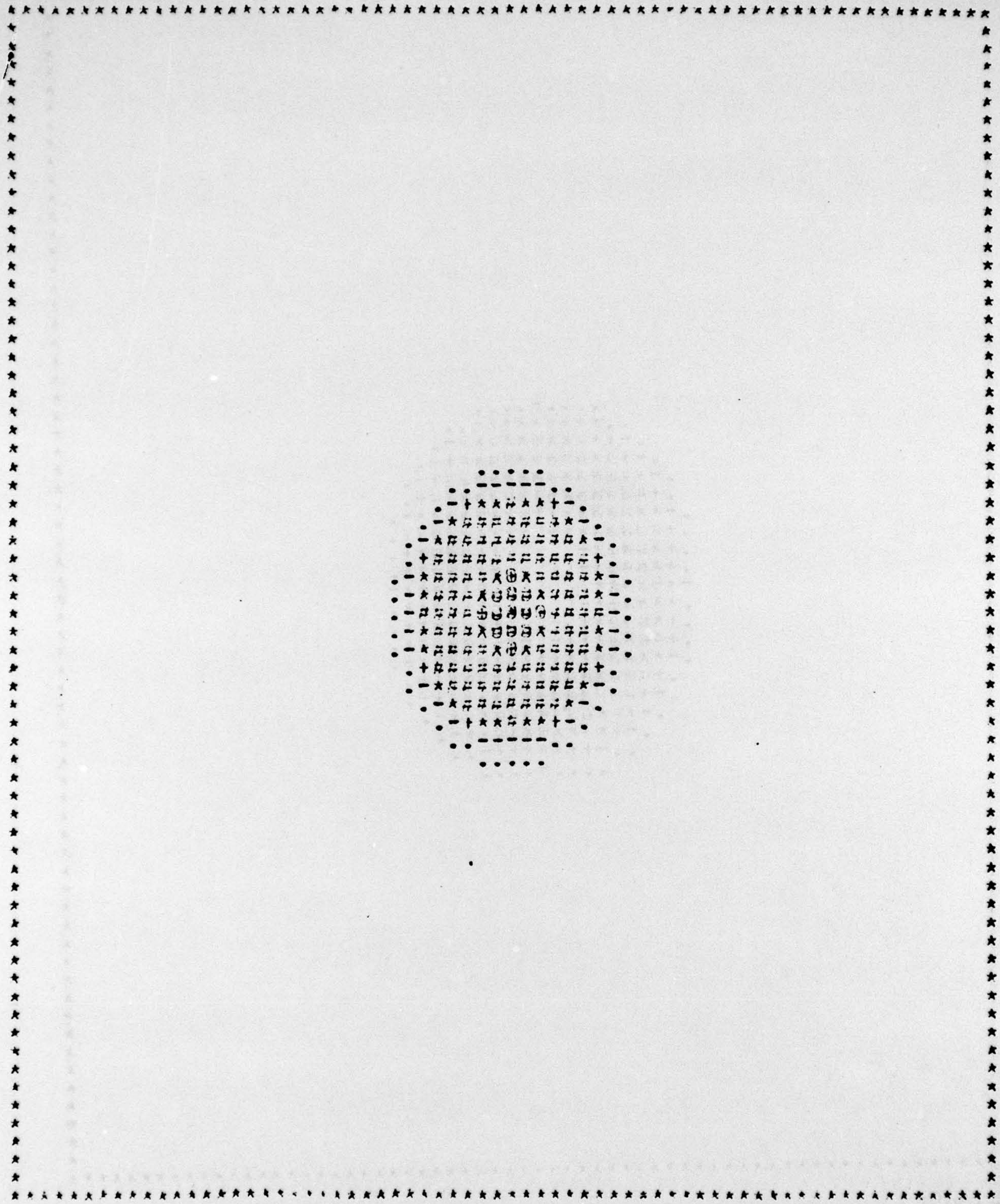


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.825269E-11	.277914E-01
.	.277914E-01	.555828E-01
-	.555828E-01	.833742E-01
+	.833742E-01	.111166E+00
*	.111166E+00	.138957E+00
=	.138957E+00	.166748E+00
X	.166748E+00	.194540E+00
$	.194540E+00	.222331E+00
@	.222331E+00	[illegible]

IRRADIANCE

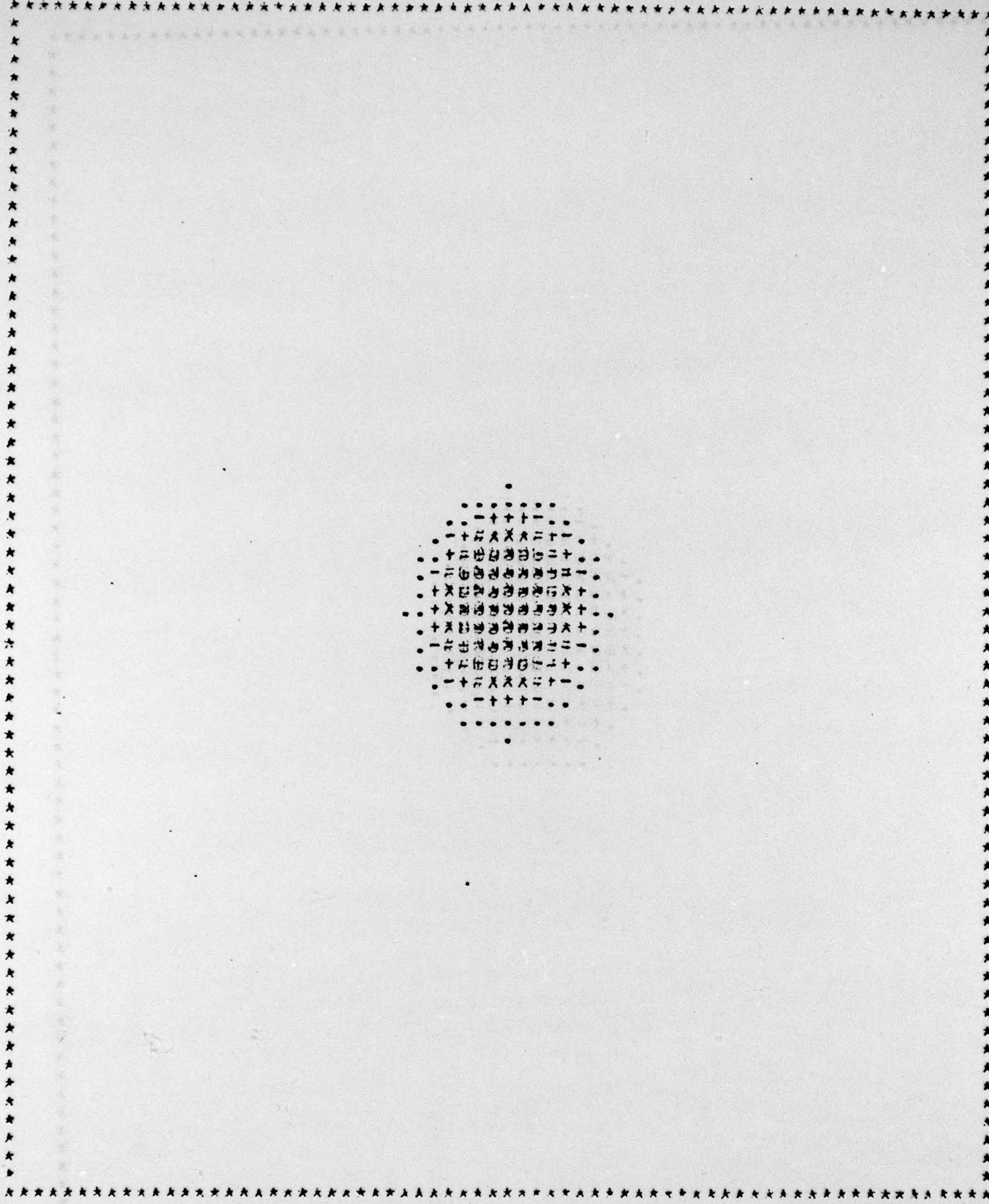


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.172623E-09	.549302E-01
.	.549302E-01	.109860E+00
-	.109860E+00	.164791E+00
+	.164791E+00	.219721E+00
*	.219721E+00	.274651E+00
=	.274651E+00	.329581E+00
X	.329581E+00	.384511E+00
#	.384511E+00	.439442E+00
@	.439442E+00	.494372E+00

IRRADIANCE

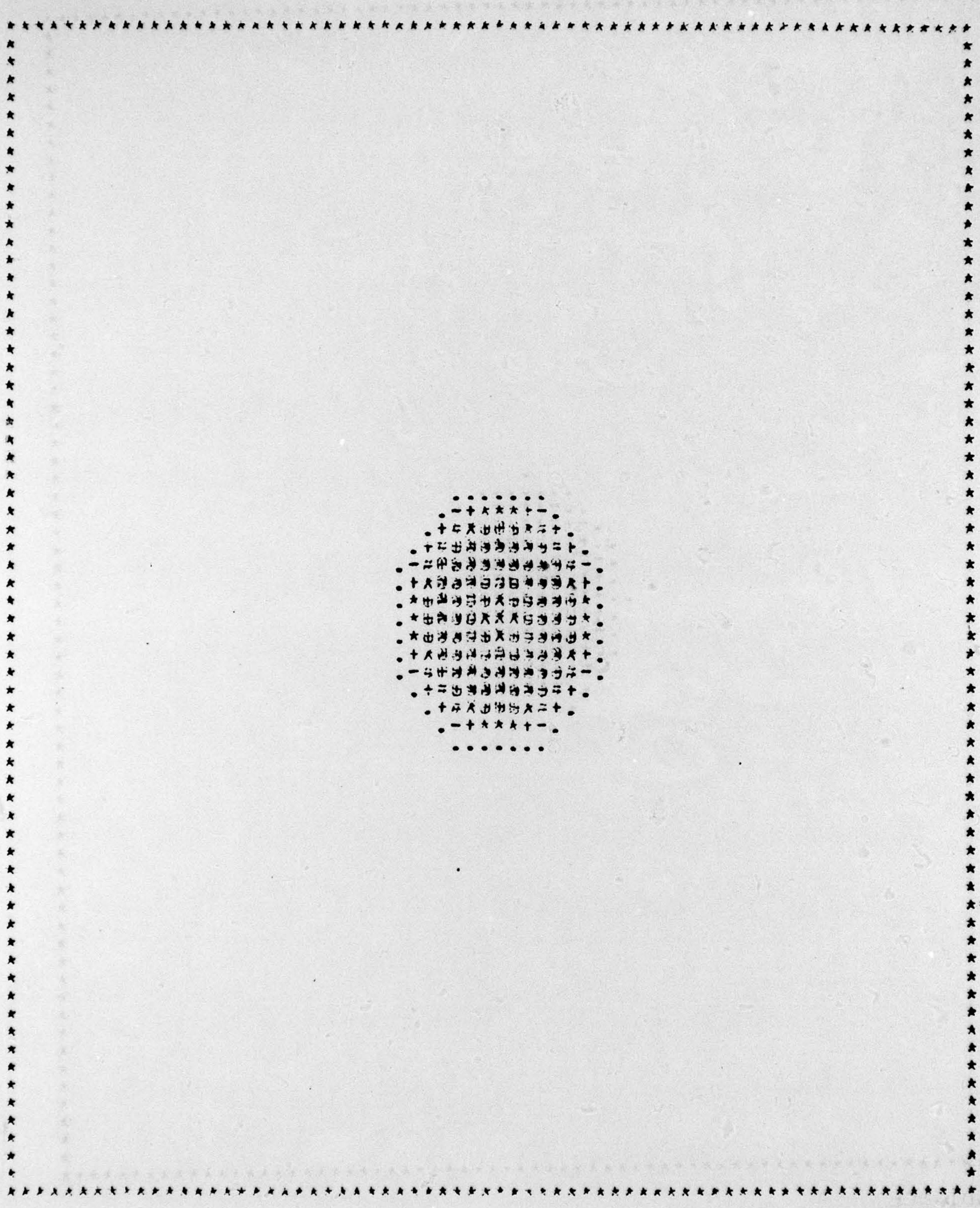


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.210571E-08	.696736E-01
.	.696788E-01	.139355E+00
-	.139358E+00	.209035E+00
+	.209036E+00	.278715E+00
*	.278715E+00	.348394E+00
=	.348394E+00	.418073E+00
X	.418073E+00	.487751E+00
@	.487751E+00	.557430E+00
#	.557430E+00	.627109E+00

IRRADIANCE

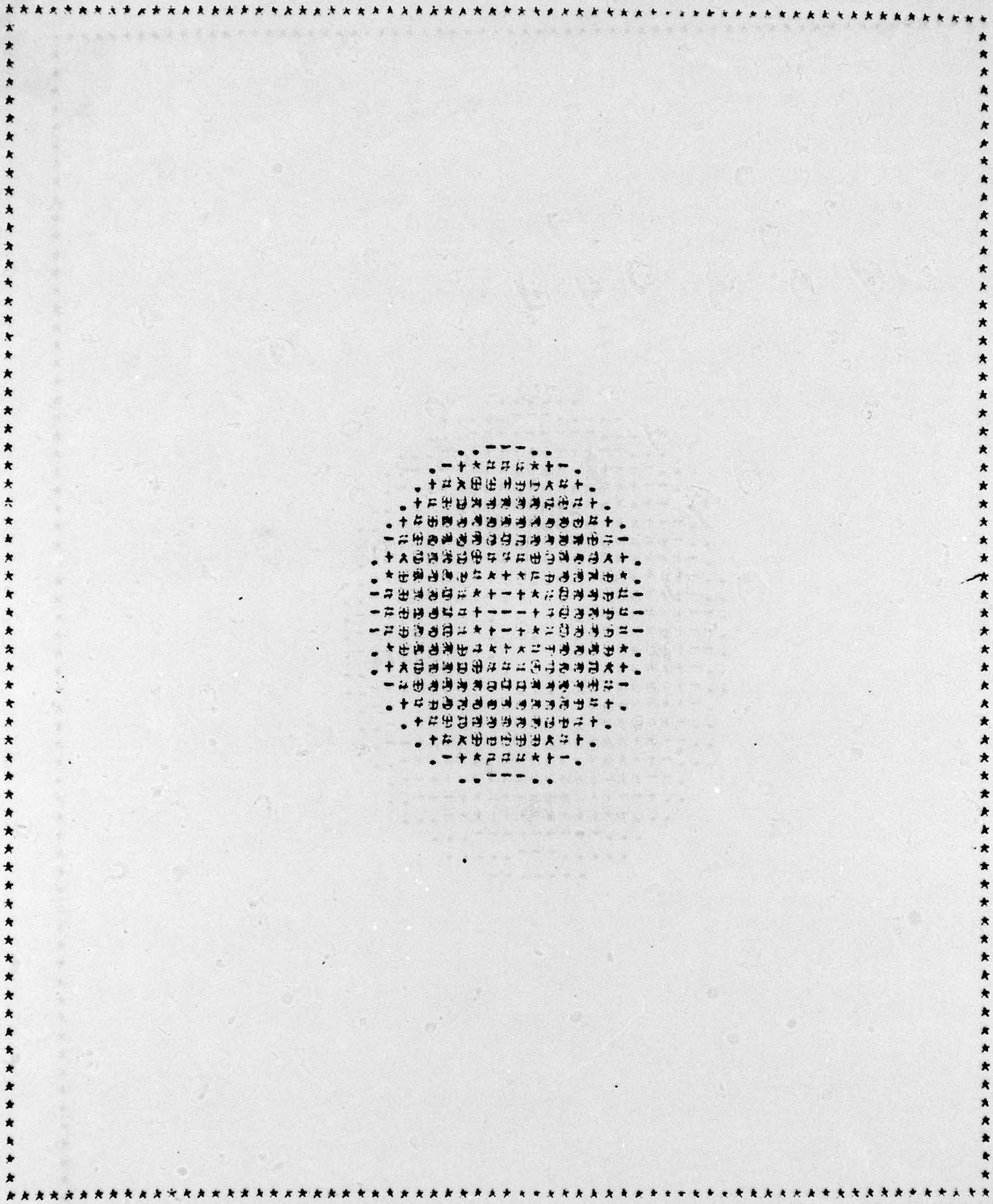


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.624851E-07	.481306E-01
.	.481306E-01	.962611E-01
-	.962611E-01	.144392E+00
+	.144392E+00	.192522E+00
*	.192522E+00	.240653E+00
#	.240653E+00	.288783E+00
X	.288783E+00	.336914E+00
[illegible]	.336914E+00	.385044E+00
[illegible]	.385044E+00	.433175E+00

IRRADIANCE

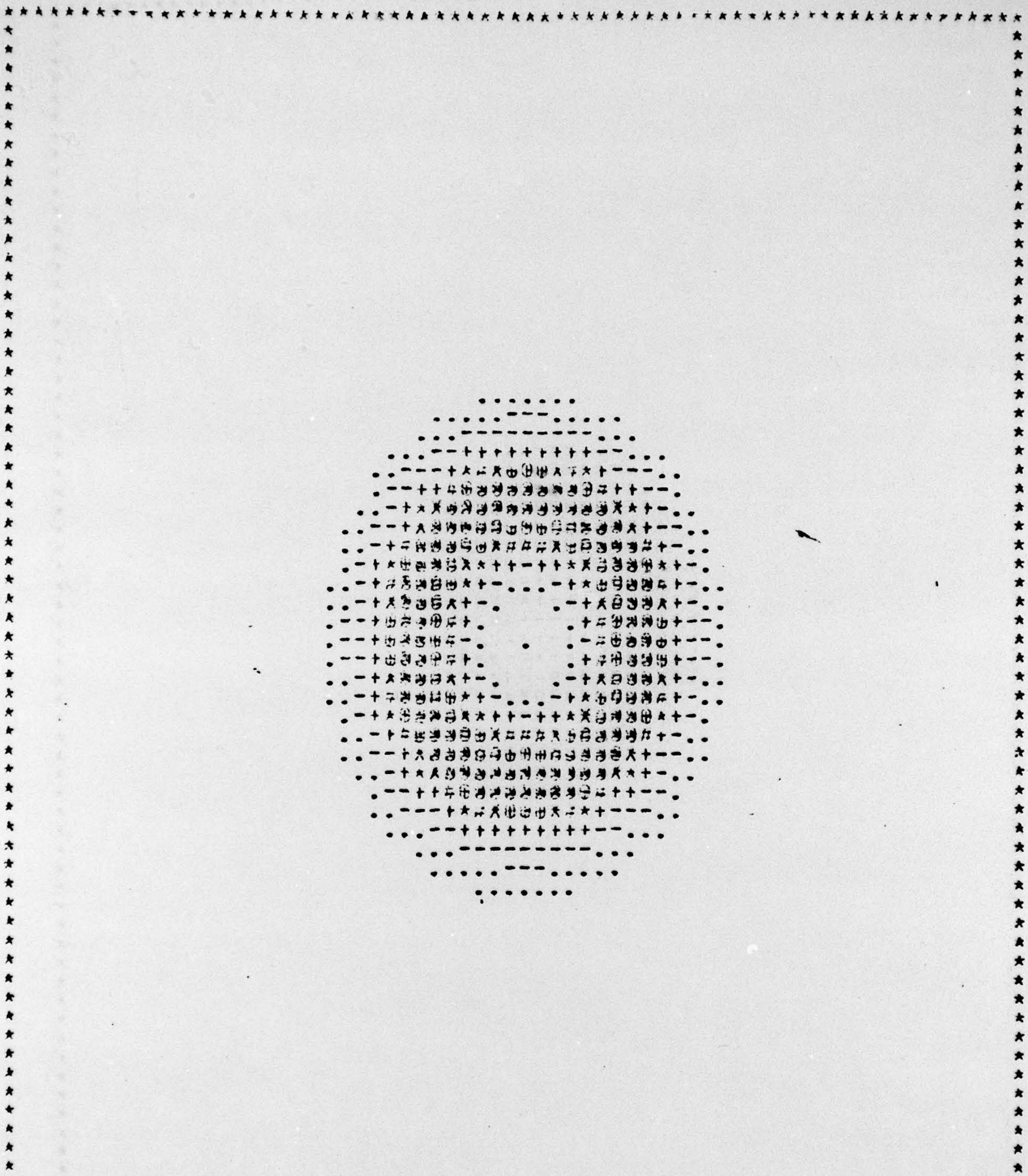


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.195300E-07	.280749E-01
.	.280749E-01	.561498E-01
-	.561498E-01	.842246E-01
+	.842246E-01	.112300E+00
*	.112300E+00	.140374E+00
#	.140374E+00	.168449E+00
X	.168449E+00	.196524E+00
@	.195524E+00	.224599E+00

IRRADIANCE

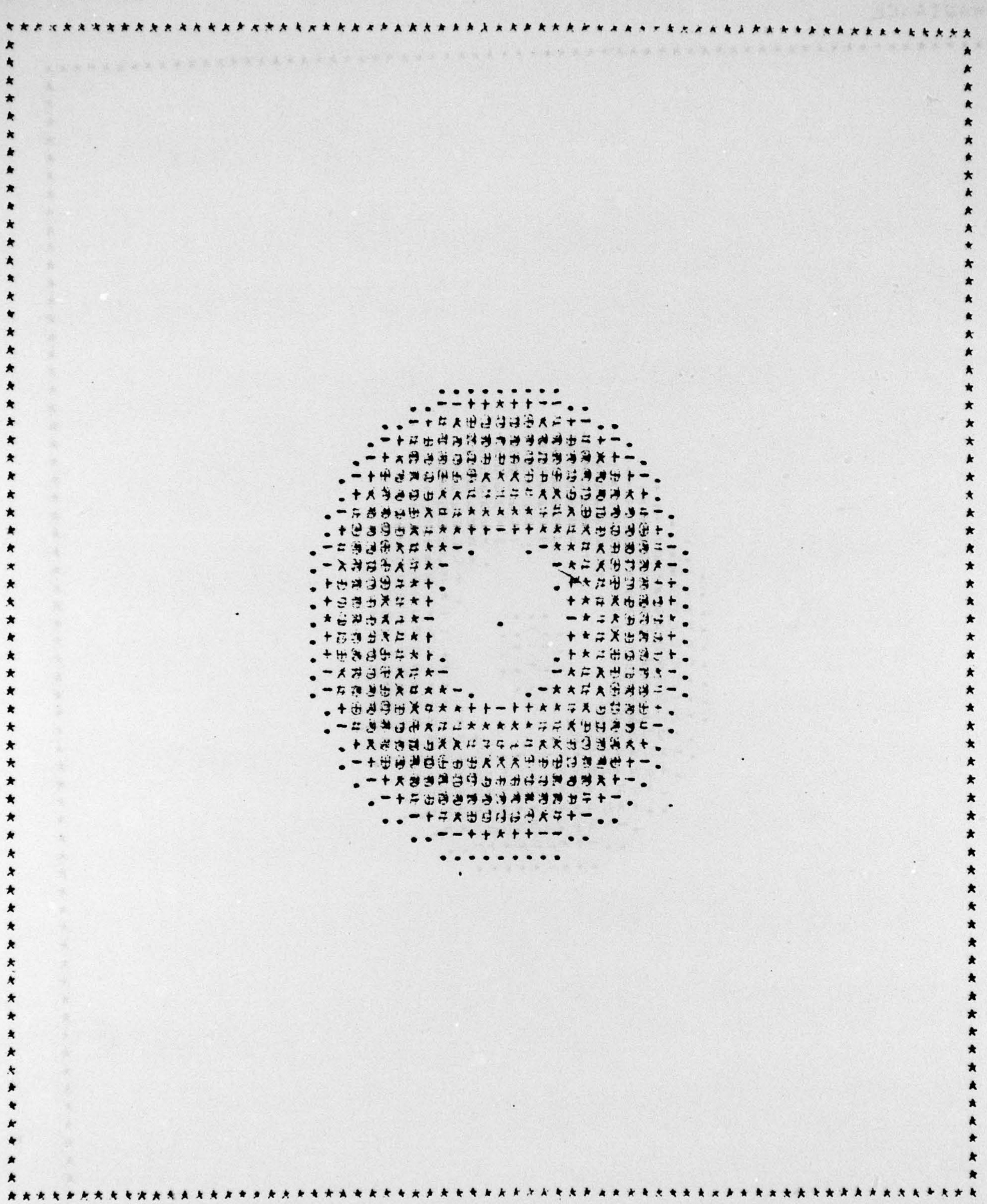


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.645125E-08	.203773E-01
.	.203773E-01	.407546E-01
-	.407546E-01	.611319E-01
+	.611319E-01	.815092E-01
*	.815092E-01	.101886E+00
#	.101886E+00	.122264E+00
X	.122264E+00	.142641E+00
⊕	.142641E+00	.163018E+00
@	.163018E+00	.183396E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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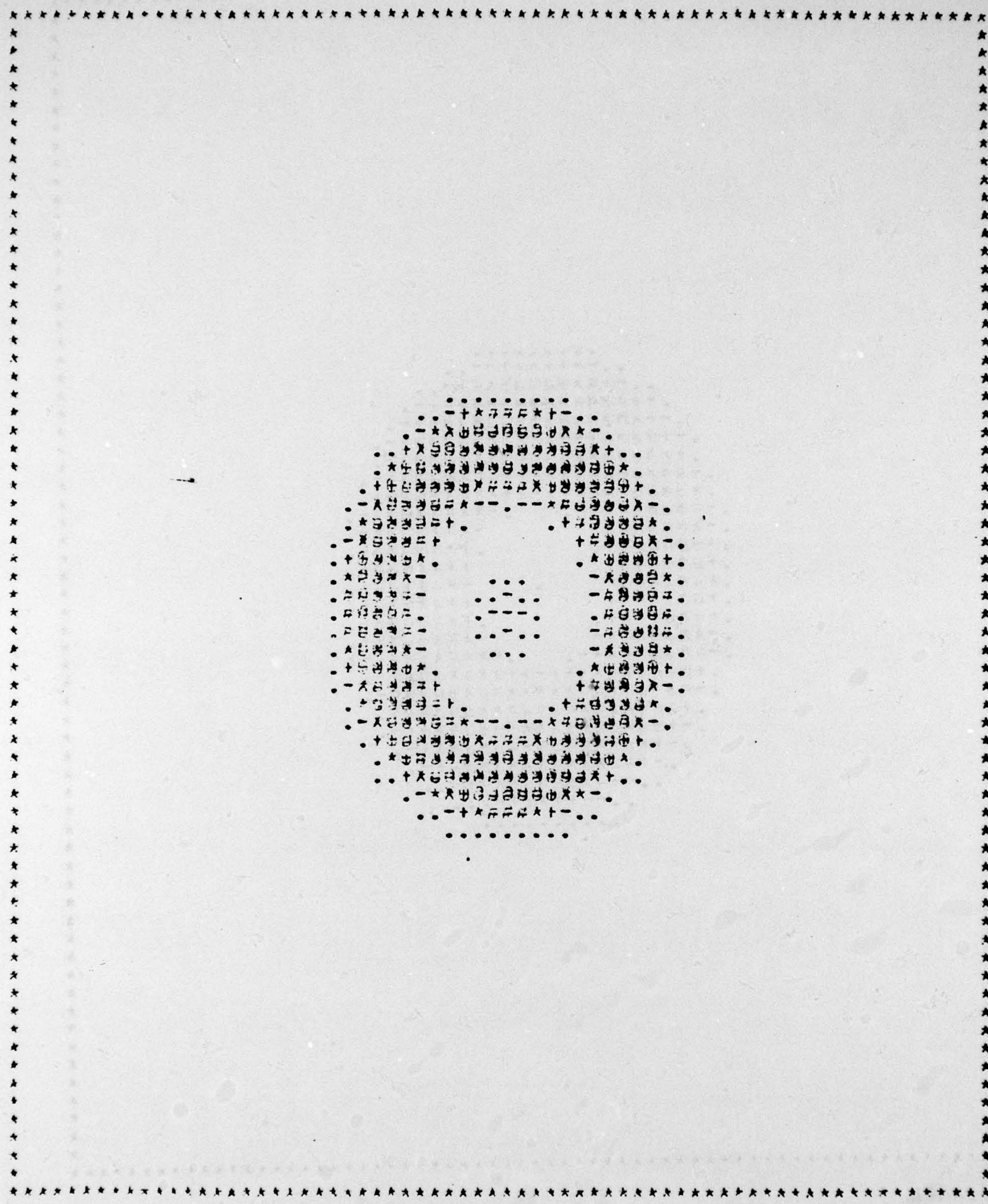
.	.179738E-01	.359476E-01
-	.359476E-01	.539215E-01
+	.539215E-01	.718953E-01
*	.718953E-01	.898691E-01
#	.898691E-01	.107843E+00
X	.107843E+00	.125817E+00
[illegible]	.125817E+00	.143791E+00

IRRADIANCE

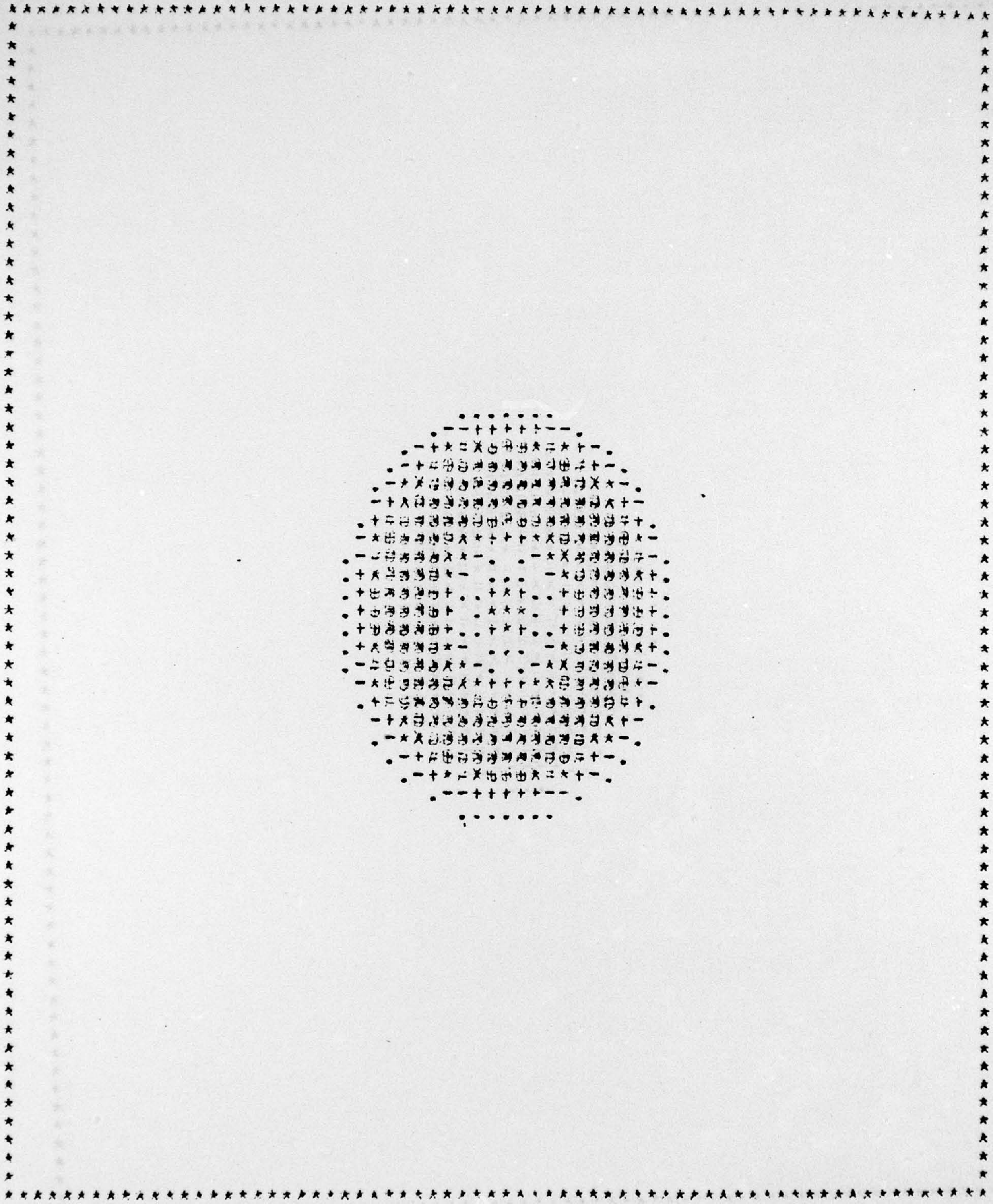


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.934771E-09	.218659E-01
.	.218659E-01	.437319E-01
-	.437319E-01	.655978E-01
+	.655978E-01	.874637E-01
*	.874637E-01	.109330E+00
=	.109330E+00	.131196E+00
X	.131196E+00	.153062E+00
⊕	.153062E+00	.174927E+00
⊞	.174927E+00	.196793E+00

IRRADIANCE

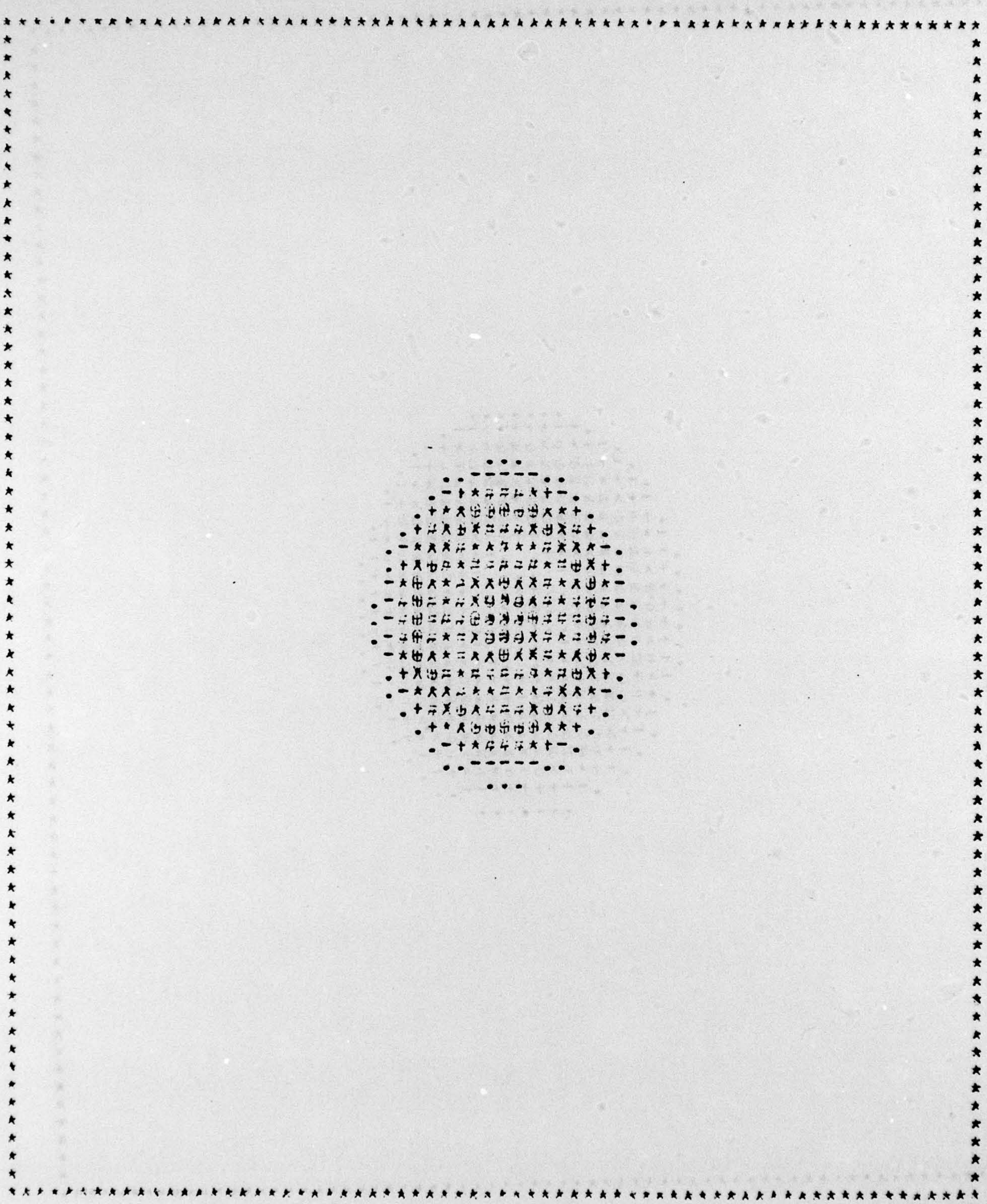


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.368173E-07	.221418E-01
.	.221418E-01	.442836E-01
-	.442836E-01	.664254E-01
+	.664254E-01	.885672E-01
*	.885672E-01	.110709E+00
#	.110709E+00	.132851E+00
[illegible]	[illegible]	[illegible]

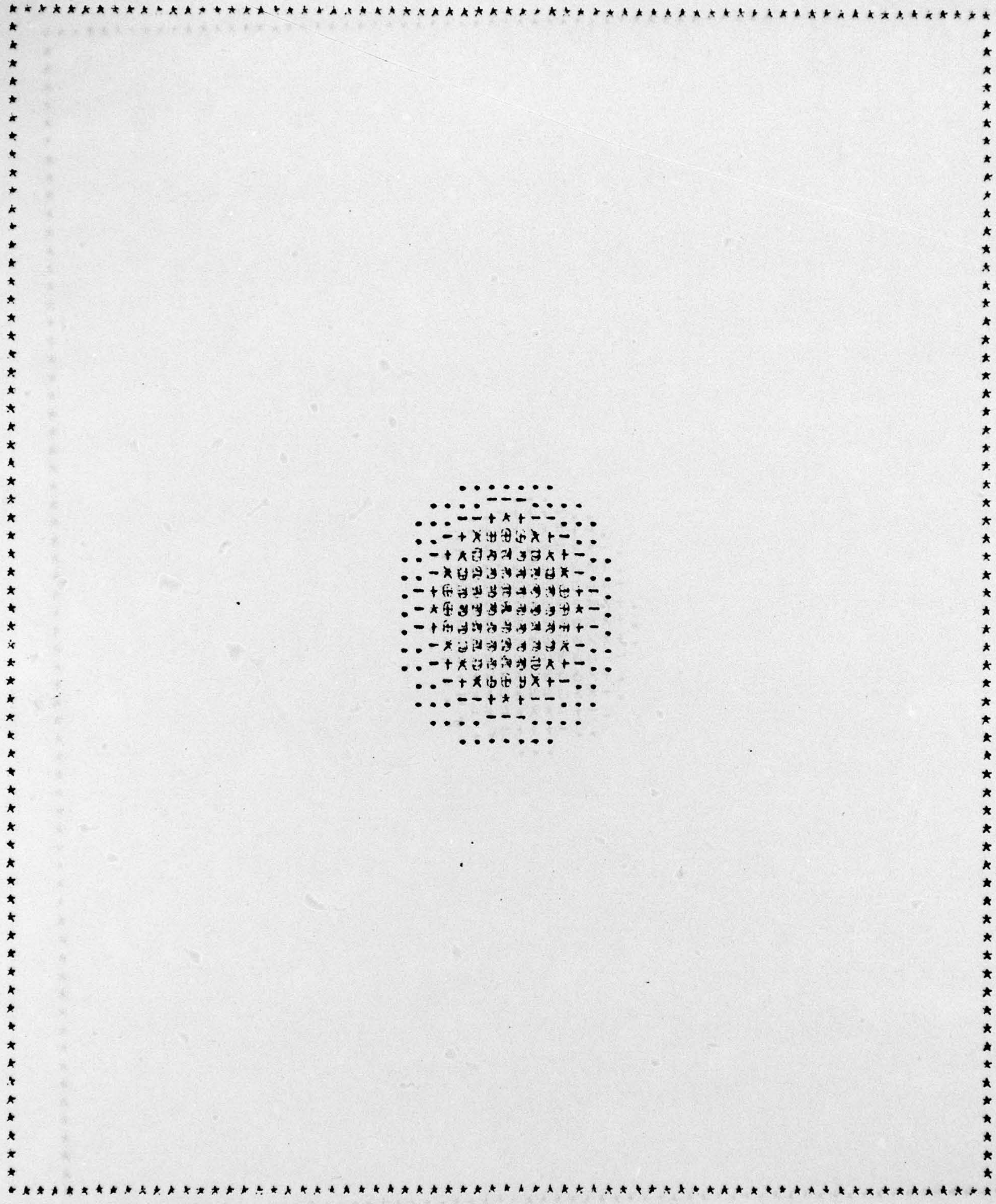
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.374430E-07	.407600E-01
.	.407600E-01	.815199E-01
-	.815199E-01	.122280E+00
+	.122280E+00	.163040E+00
*	.163040E+00	.203800E+00
=	.203800E+00	.244560E+00
X	.244560E+00	.285320E+00
@	.285320E+00	[illegible]

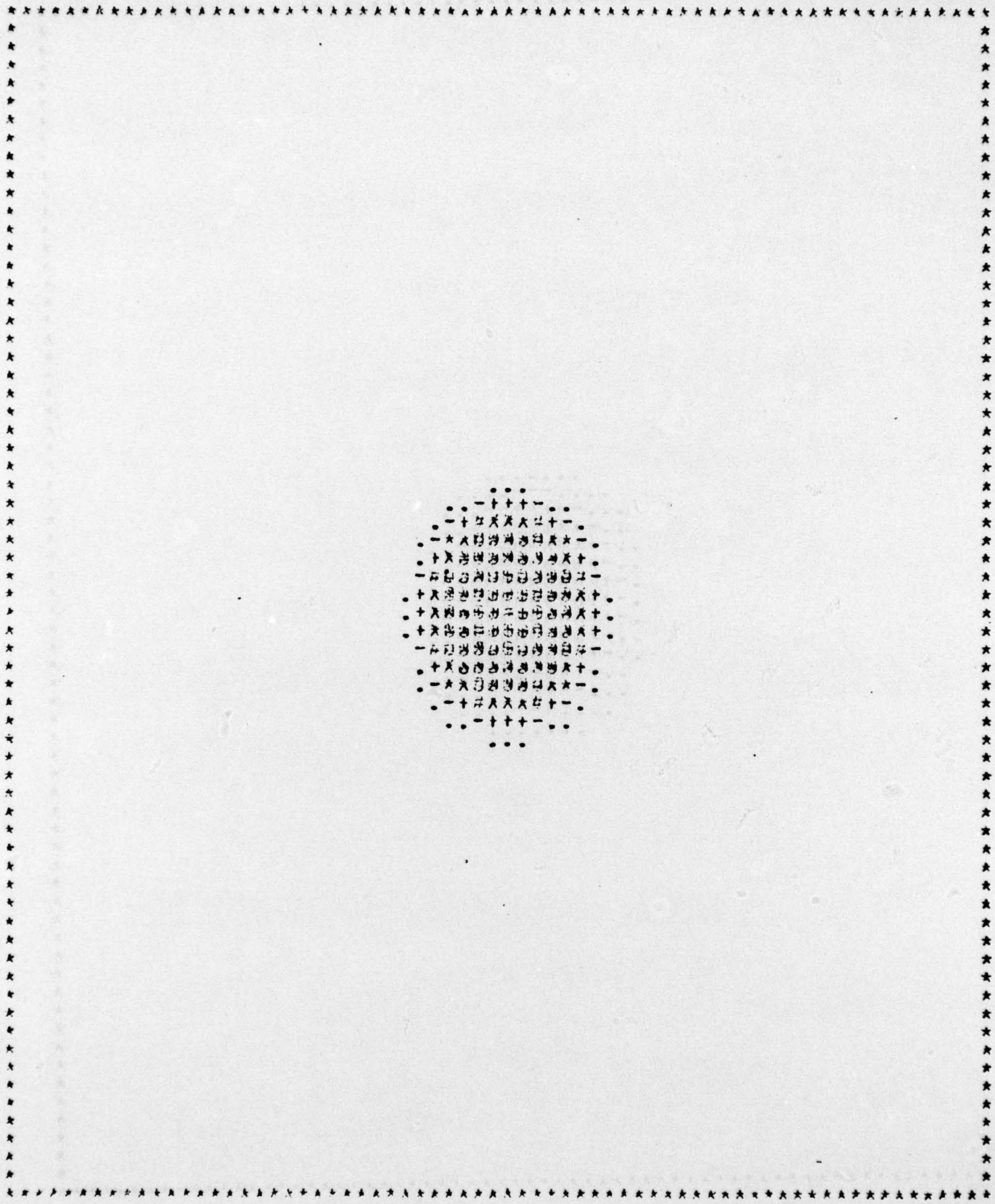


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.207193E-07	.590478E-01
.	.590478E-01	.118096E+00
-	.118096E+00	.177143E+00
+	.177143E+00	.236191E+00
*	.236191E+00	.295239E+00
=	.295239E+00	.354287E+00
X	.354287E+00	.413334E+00
@	.413334E+00	.472382E+00

IRRADIANCE

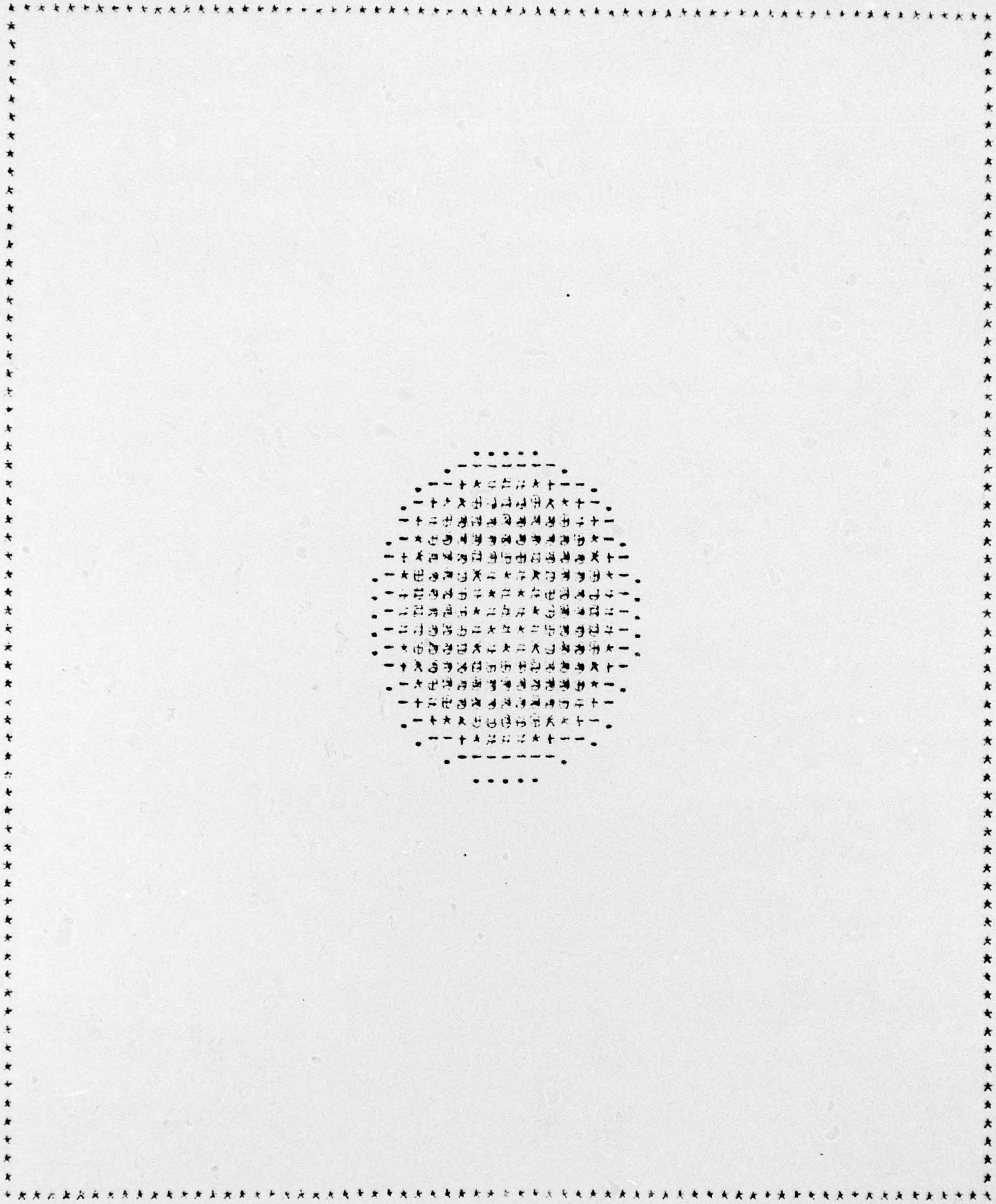


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.376973E-06	.534977E-01
.	.534977E-01	.106995E+00
-	.106995E+00	.160493E+00
+	.160493E+00	.213991E+00
*	.213991E+00	.267489E+00
=	.267489E+00	.320986E+00
X	.320986E+00	.374484E+00
0	.374484E+00	.427982E+00
#	.427982E+00	.481480E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.231555E-07	.325728E-01
.	.325728E-01	.651455E-01
-	.651455E-01	.977182E-01
+	.977182E-01	.130291E+00
*	.130291E+00	.162864E+00
=	.162864E+00	.195436E+00
x	.195436E+00	.228009E+00
[illegible]	[illegible]	[illegible]

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